THE ELECTRIC DRIVE CHARGES FORWARD

hevtcp

Annual Report 2022

Technology Collaboration Programme

by iea

HEV TCP ANNUAL REPORT 2022

This is the 2022 Annual report for the HEV TCP – an international collaboration of 19 countries exploring cutting-edge questions in hybrid and electric vehicles. This report sets out the background to the partnership, gives updates on ongoing projects and on member countries' work, and gives a set of contact details for more information.

International Energy Agency

ieahev.org

Implementing Agreement for Co-operation on Hybrid and Electric Vehicle Technologies and Programmes (HEV TCP) is an international membership group formed to produce and disseminate balanced, objective information about advanced electric, hybrid, and fuel cell vehicles. It enables member countries to discuss their respective needs, share key information, and learn from an ever-growing pool of experience from the development and deployment of hybrid and electric vehicles.

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SECTION A

Introduction

Chairperson's message

As the chairperson of the Hybrid and Electric Vehicle Technology Collaboration Programme (HEV TCP), a part of the International Energy Agency's Energy Technology Network, I have the great pleasure of introducing the 2022 Annual Report.

The work of the HEV TCP has continued to make good progress in the last year, despite the continued challenging times, which hopefully are coming to an end. Due to ongoing travel constraints imposed by COVID, the HEV TCP Executive Committee (ExCo) held two virtual meetings in 2021, and the work of the various tasks also advanced with virtual meetings and workshops.

The next ExCo meeting will be our first in-person meeting since November 2019 (Rome, Italy) and is planned to be held in conjunction with EVS35 in June 2022 in Oslo, Norway.

The EV (BEVs and PHEVs) market continued to perform better than that of conventional light vehicles in 2021. As reported by EV-volumes.com[1], and as shown in Figure 1, EVs saw a sales growth of 108% in 2021. This growth represents 8.3% of the total light vehicle market in 2021 and a doubling of the EV market share compared to 2020.

As shown in Figure 2, this 108% growth from 2020 to 2021 brings EV sales back on track with the trend observed before events of the previous two years. Compared to 2020, where significant differences in

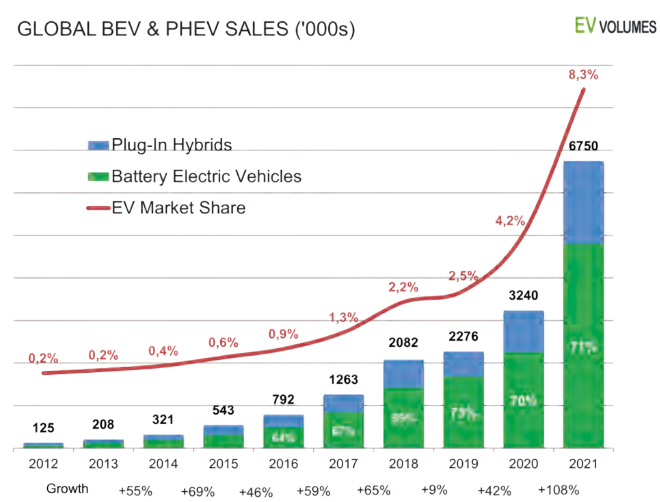

Figure 1: Global BEV & PHEV Sales

Source: https://www.ev-volumes.com/

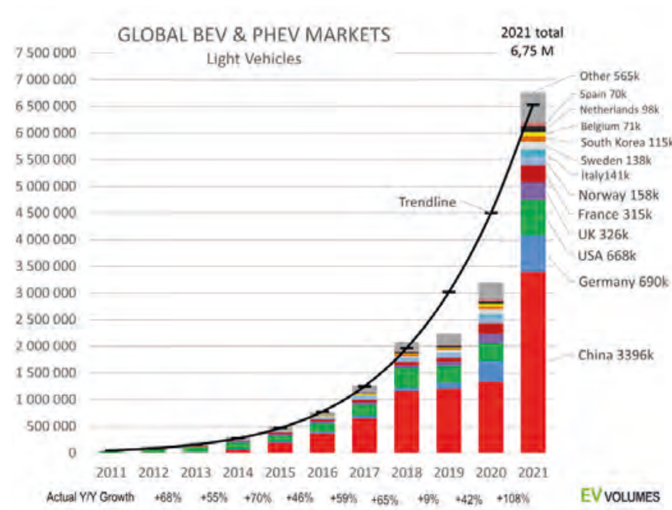

Figure 2: Global BEV & PHEV Markets – Light Vehicles

Source: https://www.ev-volumes.com/

1 https://www.ev-volumes.com/

performance were seen for Europe, Asia, and North America, in 2021 increases in EV sales were observed across the globe, with 66% for Europe, 155% for China, 96% for North America, and 115% for other regions combined. HEV TCP member countries have reported EV sales that confirm these trends, showing record EV sales increases over 2020.

The electrification of transportation is essential to meet a clear commitment to become carbon neutral by 2050, and this performance by the EV sector observed in 2021 is very encouraging. According to the IEA's Tracking Clean Energy Progress reports[2], which assess the status of critical energy technologies and sectors, the transport sector needs to undergo a major transformation. However, electric vehicles are identified as one of the few technologies that are on track with the Net Zero Emissions by 2050 Scenario.

Acknowledgements

As the Chairperson for the HEV TCP, I would like to recognize the excellent support provided by Dr. James Miller (Argonne National Laboratory) as the HEV TCP Secretary, and the generous contribution from the US Department of Energy for financing the position of the Secretary.

I would like to express my sincere thanks to both Sonja Munnix (the Netherlands) and Ock Taeck Lim (South Korea) for their support as Deputy Chairs, as well as to Celeste Ferguson and the rest of the team at Urban Foresight for their excellent work with Task 1 and providing logistical support for the virtual meetings.

In addition to the ExCo, the management of the TCP includes the work of two sub-committees, the Strategic Planning Group, and the Technical Committee (chaired by Steven Boyd, US DOE), which count on the participation of various ExCo members. My appreciation also goes out to the Operating Agents responsible for the Tasks for their excellent leadership and hard work in keeping things going during the past year, as well as to all Task participants for their continued involvement.

Lastly, yet importantly, I wish to thank the member country delegates and observers for their continued strong participation in ExCo meetings and other activities of the TCP.

CAROL BURELLE
Chairperson of the Executive Committee, Hybrid and Electric Vehicle Technology Collaboration Programme

2 https://www.iea.org/topics/tracking-clean-energy-progress

Executive Summary

Electric vehicles (EV) had a record year in 2021, despite the ongoing effects of the pandemic and the global shortage of semiconductor chips.

With 6.7 million new cars registered worldwide, EV sales more than doubled (108%), from just 3 million in 2020. Worldwide sales of EVs represented 8.3% of global light vehicle sales, compared to just 4.2% in 2020[1]. The global auto market improved by only 4.7% over the 2020 pandemic, with EVs again resilient to setbacks in demand and supply for cars. Battery electric vehicles and plug-in hybrid electric vehicles represented 71% and 29% of total EV sales respectively[2].

EV sales are expected to return to more normal growth and reach about 9.5 million, higher if remaining supply and logistics problems are resolved.

Currently, 90% percent of global electric car sales are accounted for by China, Europe, and the United States.

HEVTCP Overview

With a membership of 18 countries, the HEVTCP works together on joint projects (tasks) to better understand and address EV deployment challenges and provide guidance to policy makers. In 2021, these members have continued to actively participate in tasks and pursue their transport electrification agenda.

The TCP initiated three new tasks in 2021, namely:

- Task 46 on "Life cycle analysis of electric trucks, buses, and two-wheelers"
- Task 47 on "Electrification of ground goods movement in ports"
- Task 48 on "Battery swapping"

In 2021, the TCP closed the following Tasks, for which final reports are available for download on the HEV-TCP website at www.ieahev.org:

- Task 32: Small Electric Vehicles
- Task 42: EV Cities Casebook

Based on the work conducted under the HEVTCP, two books were published. These were "Small Electric Vehicles: An International View on Light Three- and Four-Wheelers", Amalie Evert et al, Springer, April 22, 2021, and "3rd EV City Casebook and Policy Guide: Scaling Up to Mass Adoption", Urban Foresight, 11 March 2021.

The TCP currently manages a total of 14 Tasks. The table overleaf below provides a summary of the tasks in this report.

In other news, the HEVTCP undertook a website revamp. The new website allows users to filter through closed and ongoing tasks and publications. Users will also be able to easily find information on which tasks each country is participating or has participated in.

Additionally, the HEVTCP newsletter has gained traction, showcasing policy and deployment updates from selected member countries and tasks, these are available on the HEVTCP website. The next edition of this quarterly newsletter will be released in the summer of 2022.

The November 2021 meeting of the HEVTCP ExCo was again held virtually. Due to the increased accessibility, this event was well attended. Without a host country, the knowledge sharing day focused on policy updates from several member countries, with a great update on Israel from the keynote speaker, Charlie Levine from ElectReon.

Task	Country Participants	Status	Period	Objectives
Task 1 Information Exchange	All	Ongoing	Jan 2022 -	Serves as a platform for information exchange among member countries.
Task 30 Assessment of Environmental Effects of Electric Vehicles	Austria, Canada, Germany, Spain, South Korea, Turkey, USA	Ongoing	Apr 2016 -	To analyse and assess the environmental effects of EVs on water, land use, resources, and air-based in an LCA.
Task 34 Batteries	Canada, Germany, Sweden	Ongoing	Apr 2016 -	To encourage the sharing and dissemination of current information about battery topics of interest to the vehicle community.
Task 35 Fuel Cell Electric Vehicles	Austria, Republic of Korea	Ongoing	Jan 2017 -	To analyse the technology required for FCVs and hydrogen stations and to disseminate the policy of FCVs and hydrogen station.
Task 37 Extreme Fast Charging	USA	Ongoing	Jan 2017 -	To investigate station siting, quantify the costs of installation, document grid connection details, understand the implications of XFC on battery design, performance, and cost, and study consumer education methods and topics.
Task 38 Marine Application (e-ships)	Canada, China, Norway.	Restarted in 2021	Oct 2017 -	To provide an overview and encourage the development and deployment of e-Ships, by building and sharing key knowledge on projects, performance, segments, and demand.
Task 39 Interoperability of e-mobility services	Belgium, Canada, France, Spain, Switzerland, The Netherlands, United States	Ongoing	Jan 2018 -	To bring together experts from member countries to share information and best practices to improve the interoperability and accessibility of charging services.
Task 40 CRM4EV: Critical Raw Materials for EVs	Austria, France, Germany, Netherlands, Norway, Republic of Korea, Spain, Sweden, USA, UK;	Ongoing	Apr 2018 -	To build a global representative network on the topic "Critical Materials for EVs" with stakeholders from administrations, industry, policymakers, researchers, and other relevant stakeholders representing the different value chains of the identified "in-scope" critical materials.

Task	Country Participants	Status	Period	Objectives
Task 41 Electric Freight Vehicles	Austria, Germany, Switzerland, Turkey and United Kingdom.	Ongoing	Apr 2019 -	To monitor progress and review relevant aspects for a successful introduction of electric freight vehicles (EFV) into the market.
Task 42 EV City Casebook	Canada, Denmark, Germany, The Netherlands, United Kingdom	Closed	Nov 2018 – Mar 2021	To collect learnings and best practices from existing and planned large scale deployments of EVs around the world.
Task 43* Vehicle-Grid Integration	Belgium, Canada, Denmark, France, Germany, Ireland, Italy, the Netherlands, Republic of Korea, Spain, Switzerland, United Kingdom, United States	Ongoing	Apr 2019 -	To explore, identify, and give answers to the gaps preventing electric vehicles to be fully integrated into the electrical grid.
Task 45 Electrified Roadways (E-Roads)	USA, Norway, The Netherlands, Switzerland	Ongoing	Jan 2021 -	To develop a greater global understanding and awareness of ERoads, related deployment activities, and technologies developed to advance electric mobility.
Task 46 LCA of Electric Trucks, Buses, Two wheelers and Other Vehicles	Austria, Germany, Republic of Korea, Spain, Switzerland, United States	Ongoing	Feb 2022 -	Analyse, discuss, and document the environmental impacts based on life cycle assessment of electric buses, trucks, two-wheelers, and other vehicles (mining, agriculture, train, etc.)
Task 47* Electrification of ground goods movement in ports	Norway, United States	Ongoing	Nov 2021 -	Investigate and leverage port electrification technology deployment to enable adoption of electrified ground transportation vehicles which support port activities, with a secondary focus on grid capacity/integration methodologies to create a resilient power supply.
Task 48 Battery Swapping	China, Germany	Ongoing	Nov 2021 -	Focus on creating stronger infrastructure for battery swapping technology and swapping of information.

*Updates on HEVTCP website only

[1] www.ev-volumes.com

[2] IEA (2021), Electric Vehicles, IEA, Paris www.iea.org/reports/electric-vehicles

The IEA & the HEV TCP

This chapter introduces the International Energy Agency (IEA) and its Technology Collaboration Programme for Co-operation on Hybrid and Electric Vehicle Technologies and Programmes (HEV TCP). In 2015, the IEA rebranded the Implementing Agreements as Technology Collaboration Programmes (TCPs).

IEA TECHNOLOGY COLLABORATION PROGRAMMES

The IEA provides a legal framework for international collaborative energy technology RD&D (Research, Development, and Deployment) groups, through multilateral technology initiatives known as Technology Collaboration Programmes (TCPs). A TCP may be created at any time, provided that at least two IEA members agree to collaborate. There are currently 39 TCPs covering fossil fuels, renewable energy, efficient energy use (in buildings, electricity, industry and transport), fusion power, and two cross-cutting TCPs dealing with technology systems modelling and women in energy. The TCP for Co-operation on Hybrid and Electric Vehicle Technologies and Programmes (HEV TCP) reports to the Working Party on Energy End-Use Technologies (EUWP). An overview of the activities of all the TCPs is available on the IEA web site.

IEA TCPs embrace numerous other activities that enable policy makers and experts from IEA-member and non-member countries to share views and experiences on energy technology issues. Through published studies and workshops, these activities are designed to enhance policy approaches, improve the effectiveness of research programmes and reduce costs.

Over three decades of experience have shown that the TCPs contribute significantly to achieving faster technological progress and innovation at a lower cost. Such international co-operation helps to eliminate technological risks and duplication of effort while facilitating processes, such as harmonization of standards. Special provisions are applied to protect intellectual property rights.
The "IEA Framework for the Technology Collaboration Programme" defines the minimum set of rights and obligations of participants in IEA TCPs. Participants are welcomed from IEA member and non-member countries, the private sector, and international organisations.

Participants in TCPs fall into two categories: Contracting Parties and Sponsors.

- **Contracting Parties** may be governments of OECD member countries and non-member countries (or entities nominated by them). They can also be international organisations in which governments of OECD member and/or non-member countries participate, such as the European Commission. Contracting Parties from OECD non-member countries or international organizations are not entitled to more rights or benefits than Contracting Parties from OECD member countries.

- **Sponsors,** notably from the private sector, may be entities of either OECD member or non-member countries that have not been designated by their governments. The rights or benefits of a sponsor cannot exceed those of Contracting Parties designated by governments of OECD non-member countries, and a sponsor may not become a chair or vice-chair of a TCP.

The TCP mechanism is flexible and accommodates various forms of energy technology co-operation among participants. It can be applied at every stage in the energy technology cycle, from research, development, and demonstration through validation of technical, environmental, and economic performance and on to final market deployment. Some TCPs focus solely on information exchange and dissemination.

Financing arrangements for international co-operation through TCPs are the responsibility of each TCP. The types of TCP financing fall into three broad categories:

1. Cost-sharing, in which participants contribute to a common fund to finance the work.
2. Task-sharing, in which participants assign specific resources and personnel to carry out their share of the work.
3. Combinations of cost and task sharing (such as in the case of the HEV TCP).

In March 2008, the Transport Co-ordination Group (TCG), under the oversight of the EUWP Vice Chair for Transport, was created with the objective of strengthening collaboration among transport-related TCPs. HEV TCP actively participates in the TCG.

TECHNOLOGY COLLABORATION PROGRAMME ON HYBRID AND ELECTRIC VEHICLES

Most IEA countries have issues with urban air quality, and all IEA countries have issues with greenhouse gas emissions from automobiles and other vehicles. Today there exists a range of technologies available to address these problems - most notably hybrid and electric vehicles. There is a strong case for the existence of an IEA TCP dedicated to developing and deploying these vehicles.

The HEV TCP was created in 1993 to collaborate on pre-competitive research and to produce and disseminate information. HEV TCP is now in its sixth five-year term of operation that runs from March 2020 until March 2025. The 18 active Contracting Parties (member countries) as of May 2021 are Austria, Belgium, Canada, China, Denmark, Finland, France, Germany, Ireland, Italy, The Netherlands, Norway, Republic of Korea, Spain, Sweden, Switzerland, United Kingdom, and the United States.

Compared to the automotive industry and certain research institutes, HEV TCP is a relatively small organisation. Nevertheless, HEV TCP is still playing an important role by (1) focusing on a target group of national and local governments and government-supported research organizations and (2) providing a forum for different countries to co-operate in joint research and information exchange activities. More countries are invited to join the Agreement and to benefit from this international co-operation on hybrid and electric vehicles.

The work of HEV TCP is governed by the Executive Committee (“ExCo”), which consists of one member designated by each Contracting Party. Contracting Parties are either governments of IEA countries or parties designated by their respective governments. The HEV TCP ExCo meets twice a year to discuss and plan the working programme. The actual work on hybrid and electric vehicles is done through a variety of different Tasks that are focused on specific topics. Each topic is addressed in a Task, which is managed by an Operating Agent (OA) - before 2011 these task forces were called Annexes. The work plan of a new Task is prepared by an interim OA, either on the OA’s own initiative or on request of the ExCo, and the work plan is then submitted for approval to the HEV TCP ExCo. The Tasks that were active during 2020 and in early 2021 are described in part B of this report. The activities associated with hybrid and electric vehicles in individual HEV TCP member countries can be found in part C.

The next three subsections briefly report on HEV TCP activities and results in the different phases of operation. The strategy for the current term of operation, Phase 6 (2020-25), and its details are reported below.

Description and Achievements of HEV TCP Phase 2, 1999-2004

Phase 2 of the HEV TCP started in November 1999 at a time when the first hybrid vehicle – the Prius – had just been introduced to the market, and battery electric vehicles were only considered suitable only for some market niches. Although good progress had been made in battery technology; low-cost, high-performance traction batteries were not yet commercially available. Progress with fuel cell technology led to optimism about a “hydrogen economy”, and car manufacturers switched their attention to fuel cells and away from battery electric vehicles.

The Tasks which ran in Phase 2 were:

- Task 1: Information Exchange - structured information exchange and collection of statistics
- Task 7: Hybrid vehicles
- Task 8: Deployment strategies for hybrid, electric, and alternative fuel vehicles
- Task 9: Clean city vehicles
- Task 10: Electrochemical systems

Description and Achievements of HEV TCP Phase 3, 2004-2009

The emphasis during Phase 3 of the Agreement, from 2004 to 2009, was on collecting information on hybrid, electric, and fuel cell vehicles, with the same value-added aspects as in the previous phase. Governmental objectives of improving air quality and energy efficiency – and of reducing greenhouse gas emissions and dependence on petroleum fuel – ensured that the need continued for the HEV TCP's mission.

HEV TCP's other achievements during Phase 3 included contributing to the IEA's technology roadmap for electric and hybrid vehicles; as well as a move to interact more closely with different IAs of the International Energy Agency, which contains transportation as an item in their work programme.

The Tasks which ran in Phase 3 were:

- Task 1: Information Exchange - the work includes country reports, census data, technical data, behavioural data, and information on non-IEA countries
- Task 10: Electrochemical Systems
- Task 11: Electric Bicycles, Scooters, and Lightweight Vehicles
- Task 12: HEVs and EVs in Mass Transport and Heavy-Duty Vehicles
- Task 13: Market Aspects of Fuel Cell Electric Vehicles
- Task 14: Market Deployment of Electric Vehicles
- Task 15: Plug-in Hybrid Electric Vehicles

Description and Achievements of HEV TCP Phase 4, 2009-2015

Interest in Hybrid and Electric Vehicles as a means to reduce energy consumption and emissions from road transport increased significantly worldwide. At the same time, many questions remain still to be answered regarding potential efficiency improvements, safety, durability, vehicle range, production potential, and the availability of raw materials for batteries, as well as issues associated with the impact on electricity grid management, standardization, the potential to introduce renewable energy in road transport, and market introduction strategies. There is a strong need for objective and complete information about these issues in order to enable balanced policy making regarding energy security, economic development and environmental protection, and the role that hybrid and electric vehicles can play.

The Tasks which ran in Phase 4 were:

- Task 1: Information Exchange
- Task 17: System Optimization and Vehicle Integration - to study how EV system configurations (including vehicle components) could be optimized for enhanced overall EV performance.
- Task 18: EV Ecosystems - to create a roadmap of the conditions required to support market growth needed for the mass adoption of EVs in cities.
- Task 19: Life Cycle Assessment of EVs - to explore the sustainable manufacture and recycling of EVs.
- Task 20: Quick Charging - to discuss the impacts and potential standards for EV quick charging.
- Task 21: Accelerated Ageing Testing for Li-ion Batteries - for collaboration on such testing efforts.
- Task 22: E-Mobility Business Models - to understand new revenue opportunities and ways to limit costs associated with EVs, recharging infrastructure, and associated links to energy systems.

- Task 23: Light-Electric-Vehicle Parking and Charging Infrastructure
- Task 24: Economic Impact Assessment of E-Mobility

Description and Strategy of HEV TCP Phase 5, 2015-2020

This phase of the HEV TCP focused on producing objective information for policy and decision makers on hybrid and electric vehicle technology, projects and programmes, and their effects on energy efficiency and the environment. By general studies, assessments, demonstrations, comparative evaluations of various options of application, market studies, technology evaluations, the HEV TCP focused on being a platform for reliable information on hybrid and electric vehicles.

The Tasks which ran in Phase 5 were:

- Task 1: Information Exchange
- Task 10: Electrochemical Systems
- Task 21: Accelerated ageing testing for lithium-ion batteries
- Task 23: Light electric vehicle parking and charging infrastructure
- Task 24: Economic impact assessment of e-mobility
- Task 25: Plug-in Electric Vehicles
- Task 26: Wireless power transfer for electric vehicles
- Task 27: Electrification of transport logistic vehicles
- Task 28: Home grids and V2X technologies
- Task 31: Fuels and Energy Carriers for Transport
- Task 39: Interoperability of E-mobility Services
- Task 40: Critical Raw Material for Electric Vehicles (CRM4EV)
- Task 41 “Electric Freight Vehicles”, and
- Task 42 “Scaling Up EV Markets and EV City Casebook
- Task 43 “Vehicle/Grid Integration

Description and Strategy of HEV TCP Phase 6, 2020-2025

In November 2019, the IEA Committee on Energy Research and Technology (CERT) approved the sixth phase of operation for HEV TCP, which is scheduled to run from 1 March 2020 until 29 February 2025. In the strategic plan for Phase 6, the participants in HEV TCP have formulated their expectations for the time frame 2020-2025.

The HEV TCP ExCo considers policy/decision makers in governmental bodies at national, regional and city levels, in the automotive industry, its component suppliers and utilities as the target audience for its work. These include the HEV TCP Contracting Parties, which are representing national governments. The HEV TCP mission is defined as to advance the mass adoption of the electric drive by: supplying objective information to support decision making; facilitating international collaboration in pre-competitive research and development (R&D), demonstration and deployment projects; identifying future research areas; fostering the international exchange of information and experiences; and identifying and removing barriers.

Against this background and to fulfil its mission, the HEV TCP Executive Committee has formulated the following strategic objectives for Phase 6 (2020-2025):

- Maintain and expand its network of experts to provide meaningful contributions to technology development and policy analyses in the face of mass adoption;

- Expand focus towards electrification of other transport modes and e-mobility in a broad sense, and strengthen the research on links with future mobility systems, such as shared, connected and automated mobility;

- Strengthen its collaborations with other TCPs and other relevant research/policy groups; and

- Involve industry in its tasks to a greater extent to provide a broader network of experts and business expertise.

The existing HEV TCP working method, including meeting twice a year for information exchange and running projects in the form of Tasks, has proven to be appropriate to achieve the objectives of the Agreement, and no changes in the working method are anticipated for the sixth phase.

HEV TCP Tasks which were active at the start of Phase 6:

- Task 1: Information Exchange
- Task 23: Light electric vehicle parking and charging infrastructure
- Task 29: Electric, connected, and automated vehicles
- Task 30: Assessment of environmental effects of electric vehicles
- Task 32: Small electric vehicles
- Task 33: Battery electric buses
- Task 34: Batteries
- Task 35: Fuel cell electric vehicles
- Task 37: Extreme fast charging
- Task 39: Interoperability of e-mobility services
- Task 40: Critical raw materials for EVs (CRM4EV)
- Task 41: Electric freight vehicles
- Task 42: EV Cities casebook
- Task 43: Vehicle/grid integration
- Task 44: Impact of Connectivity and Automation on Electrified Vehicle Usage and Benefits
- Task 45: Electrified Roadways – eRoads
- Task 46: LCA of Electric Trucks, Buses, Two-wheelers, and Other Vehicles
- Task 48: Battery Swapping

IEA ENGAGEMENT IN OTHER ACTIVITIES RELATED WITH ELECTRIC VEHICLES: THE ELECTRIC VEHICLE INITIATIVE

The Electric Vehicle Initiative (EVI www.cleanenergyministerial.org/initiative-clean-energy-ministerial/electric-vehicles-initiative and www.iea.org/areas-of-work/programmes-and-partnerships/electric-vehicles-initiative) is a multi government policy forum established in 2009 under the Clean Energy Ministerial (CEM), a high-level global forum to promote policies and programmes that advance clean energy technology, to share lessons learned and best practices and to encourage the transition to a global clean energy economy.

The EVI is dedicated to accelerating the deployment of EVs worldwide. It brings together representatives of its member governments and partners twice per year and acts as a platform for knowledge-sharing on policies and programmes that support EV deployment. As of early 2021, governments currently active in the EVI include Canada, Chile, China, France, Germany, Finland, India, Japan, the Netherlands, New Zealand, Norway, Poland, Portugal, Sweden, United Kingdom, and United States. This group includes the largest and most rapidly growing EV markets worldwide and accounts for the vast majority of global EV sales. Canada and China are the co-leads of the initiative. The International Energy Agency serves as the EVI co-ordinator. Its EV30@30 Campaign, launched at the Eighth Clean Energy Ministerial in 2017 and subscribed by most of the EVI members, redefined the EVI ambition by setting the collective aspirational goal for all EVI members of a 30 % market share for electric vehicles in the total of all passenger cars, light commercial vehicles, buses and trucks by 2030.

The implementing actions included in the EV30@30 Campaign largely define today's EVI programme of work. These actions include:

- Supporting the deployment of EV chargers and tracking progress;
- Galvanising public and private sector commitments for EV uptake in company and supplier fleets;
- Scaling up policy research, including policy efficacy analysis, information and experience sharing and capacity building;
- Supporting governments in need of policy and technical assistance through training and capacity building;
- Establishing the EVI Global Pilot City Programme (EVI-PCP), As one of the main pillars of the EV30@30 Campaign, The EVI-PCP aims to build a network of at least 100 cities over an initial period of 5 years, to work together on the promotion of electric mobility. In March 2021, EVI collaborated with the HEV TCP to release the EV City Casebook and Policy Guide (https://www.iea.org/areas-of-work/programmes-and-partnerships/evi-global-ev-pilot-city-programme)

To date, the EVI has developed analytical outputs that include the Global EV Outlook series with annual editions since 2015. The EVI has also successfully engaged private sector stakeholders in roundtables in Paris in 2010, in Stuttgart in 2012, at the annual COP meetings since 2015 and at the 2019 Paris Peace Forum to discuss the roles of industry and government in EV development as well as the opportunities and challenges ahead for EVs.In addition, other publications such as the EV Cities Casebook and Policy Guide (a joint collaboration between the IEA EVI and the HEV TCP) highlights inspiring examples and policy recommendations from cities which have taken actions to accelerate mass adoption of EVs, with the latest release in 2021. Finally, the GEF funded Global E-Mobility Programme was launched at COP26 with the aim to support low and middle income countries with a shift to electric mobility. UNEP is coordinating the implementation of the programme which includes both global thematic working groups, regional investments platforms and almost 30 country projects (with technical support and pilot projects). The work will be carried out over five years and many activities will be co-branded with the EVI, which is co-funding the work through the financial support to IEA as the coordinator. The programme also includes a tracking and monitoring framework which builds on the data collection prepared for the Global EV Outlook. Several international organisations are involved in the implementation of the programme, including the Asian Development Bank, European Bank for Reconstruction and Development (EBRD), Centro de Mario Molina and UNEP.

For the development of EVI activities, the IEA secretariat co-operates with the IEA Technology Collaboration Programmes on Advanced Fuel Cells (AFC) and Hybrid and Electric Vehicle Technologies and Programmes (HEV TCP). Other partners include: Argonne National Laboratory (ANL); C40; ClimateWorks Australia; ClimateWorks Foundation; Electrification Coalition; European Association for Electromobility (AVERE); Forum for Reforms, Entrepreneurship and Sustainability (FORES) in Sweden; Global Environment Facility; GreenTech Malaysia; International Council for Clean Transportation (which hosts the secretariat of the International Zero-Emission Vehicle Alliance); International Electrotechnical Commission (IEC); International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE); International Renewable Energy Agency (IRENA); Hewlett Foundation; King Mongkut"s University of Technology Thonburi (Thailand); Lawrence Berkeley National Laboratory; Mission 2020; Natural Resources Defence Council (NRDC); National Renewable Energy Laboratory (NREL) of the United States; Nordic Energy Research; Partnership on Sustainable, Low Carbon Transport (SloCaT); REN21; Rocky Mountain Institute (RMI); Swedish Energy Agency; The Climate Group; the United Nations Environment (UN Environment); the United Nations Human Settlements Programme (UN Habitat); the United Nations Industrial Development Organization (UNIDO); World Resources Institute (WRI) and Urban Foresight.

The HEV TCP and the EVI worked together on annual data collection, and several HEV members support the development of analytical activities in the IEA, with direct implications for the EVI deliverables, starting from the Global EV Outlook.
Key examples include the close cooperation established between the IEA and the Argonne National Laboratory on battery cost and the assessment of the greenhouse gas emissions resulting from battery manufacturing. This allows better alignment of HEV TCP and EVI data analysis and messages throughout their respective publications.

SECTION B

HEV TCP Tasks

TASK 1

Information Exchange

INTRODUCTION

HEV TCP's work is centred on information exchange, enabling members to share key policy insights and best deployment practices, as well as to identify common research interests in the rapidly growing international hybrid and electric vehicle field. Task 1 began in the first phase of HEV TCP in 1993, and continues as the main forum and portal for news and results to the wider community of the International Energy Agency (IEA).

The HEV TCP's Phase 6, running from 2020 to 2025, states that the HEV TCP "will aim to communicate and engage with key influencers of technology acceptance and deployment... The main communication vehicles will remain the same (public website, HEV TCP annual reports, workshop reports, and Task final reports), with additional journal articles and conference papers."

Table 1: Listing the Task 1 communication objectives

Task 1 Communication Objectives
Produce objective information for policy and decision makers
Disseminate information produced by HEV TCP to the IEA community, national governments, industries, and other organizations
Collaborate on pre-competitive research
Collaborate with other IEA Technology Collaboration Programmes and groups outside the IEA
Provide a platform for reliable information

OBJECTIVES

As a platform for information exchange between member countries, Task 1 aims to collect, analyse, and disseminate information on hybrid, electric, and fuel cell vehicles, and their related activities from member and non-member countries. Information exchange focuses on these topics:

- Research and technology development;
- Commercialization, marketing, sales, and procurement;
- Regulation, standards, and policies;
- Awareness raising measures; and
- Activities of HEV TCP Tasks.

WORKING METHOD

Delegates from member countries participate in Task 1 meetings, which take place every six months in conjunction with the HEV TCP Executive Committee (ExCo) meetings.

Country delegates also write country-specific information for HEV TCP publications, such as the country chapters in this annual report and quarterly newsletter.
In addition, many country delegates serve dual roles as the official Operating Agent (OA) for a specific Task. As the OA, they may also represent HEV TCP to a public audience by presenting Task results at international conferences, such as the EVS (Electric Vehicle Symposium) meetings.

The Task 1 OA is responsible for coordinating and leading the biannual experts' meetings, compiling the minutes of these meetings, maintaining the HEV TCP website, and editing and supervising the production of the newsletter and theExCo annual report.

The OA also acts as liaison to the other Task OAs, the ExCo Chair (together with the Secretary-General), and the IEA Desk Officer. Urban Foresight (United Kingdom) has been responsible for Task 1 since 2020.

The experts' meetings are an important part of the information exchange for the Task, , where participants brief the attendees on relevant reports, facts, and statistics pertaining to hybrid and electric vehicles in their home countries. These presentations generally cover current developments in the market situations for EVs and HEVs (national sales and fleet penetration, by vehicle type), the progress of international, national, or local programs and incentives in the field, and new initiatives in vehicle and component development arising from both the private sector and public-private partnerships.

Any member country of the HEV TCP can automatically participate in Task 1, free of charge. Each country designates an agency or nongovernmental organization as its Task 1 expert delegate.

Guest experts are often invited to participate in Task 1 meetings to present their activities and exchange experiences with HEV TCP participants, which is a valuable resource for staying current with global EV developments.

RESULTS

Notable events in 2021 included the following:

- The HEV TCP Annual Report on 2020 entitled The Electric Drive Continues was published in 2021.
- Task 1 managed the coordination and running of the virtually held 53rd and 54th ExCos.
- A new external facing website was designed and created, facilitated by Urban Foresight. This site was published in May 2021.
- A new HEV TCP LinkedIn account was created.
- New SharePoint folders were created to allow for external collaboration with non-members.
- Coordination for aligning the data collection templates for the HEV TCP and IEA was conducted to ensure the same data was collected and efforts were not being duplicated.
- The quarterly HEV TCP Newsletter was instated and has continued throughout 2021. To date, four issues have been published. We welcome any contributions from HEV TCP members for the next issue in Summer 2022.

NEXT STEPS

The in-person Spring meeting hosted in Oslo has been planned and will go ahead for June 8-10th. This will coincide with the 35th EVS held from the 11-15th of June. The decision on the format for ExCo 56 (fall 2022) has been deferred until we know more about hybrid meetings and their functionality.

FOR FURTHER INFORMATION, PLEASE CONTACT THE OPERATING AGENT:

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TASK 30

Assessment of Environmental Effects of Electric Vehicles

MEMBER COUNTRIES
AUSTRIA
CANADA
GERMANY
SPAIN
SOUTH KOREA
TURKEY
UNITED STATES

ACKNOWLEDGEMENT
The work of the Austrian participation (2018 – 2022) is financed by the Austrian Climate and Energy Fund and the FFG.

INTRODUCTION

Electric vehicles (EVs) have the potential to substitute conventional vehicles to contribute to the sustainable development of the transportation sector worldwide, for example, in the reduction of greenhouse gas (GHG) emissions, fossil energy consumption and particle emissions. There is international consensus that the improvement of the sustainability of EVs can only be analyzed based on life cycle assessment (LCA), which includes the production, the operation, and the end of life (EoL) management of the vehicles and the fuel cycle (Figure 1). All environmental impacts must include the whole value chain and - if relevant - interactions from recycling in the dismantling phase to the production phase if recycled material is used to produce new vehicles.

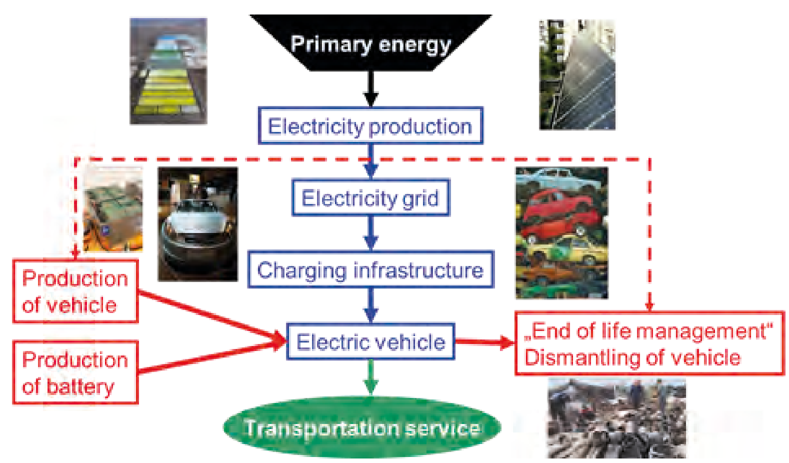

Figure 1: System boundaries for life cycle assessment of EVs

OBJECTIVES

The aim of Task 30 (2016 – 2021) was to analyze and assess environmental effects of EVs on water, land use, resources and air based on LCA in cooperation of the participating countries in the International Energy Agency (IEA) TCP.

Task 30 was using the results of the completed Task 19 "Life Cycle Assessment of Electric Vehicles" (2011 – 2015, www.ieahev.org/tasks/task-19-life-cycle-assessment-of-evs/, led by JOANNEUM RESEARCH) as a foundation to subsequently examine the environmental effects – benefits and impacts - of vehicles with an electric drivetrain (EVs), based on LCA. With an eye on the three phases of LCA, such as production, operation and dismantling of EVs, various environmental effects of EVs on water, land use, resources, and air, among others, are analyzed and assessed.

Thereby a strong accent is put on the comparison of environmental effects between pure battery EVs (BEVs) and plug-in hybrids (PHEVs) on one hand, and conventional internal combustion engine (ICE) vehicles using gasoline and diesel on the other side.

In recent years, the focus in environmental assessments of EVs was on global warming and primary energy consumption. But now it is recognized that other impacts gain additional relevance and must be addressed by life cycle-based comparisons like water, land use, resource consumption, local particle matter (PM) and NOx-emissions. Therefore, Task 30 focuses also on the following topics covering methodologies, data and case studies:

- effects of EVs on water (emissions to water, wastewater, "Water Footprint" of EVs),
- effects on EVs on air (local emissions and effects of NOx, PM and CxHy, human health effect and non-energy related emissions from tires and brakes),
- effects of EVs on land use – resources - waste (land use, occupation and degradation, demand of renewable and fossil resources, recycling), and
- overall environmental effects and their assessment (comparing and assessing different impact categories, single score methodologies, stakeholder involvement).

WORKING METHOD

Within Task 30, methodologies are developed to help countries implement EVs by identifying possibilities to maximize the environmental benefits. Besides, various case studies are analyzed and networking combined with information exchange is supported within the Task's frames (Figure 2). The Task proceeds by organizing a series of expert workshops addressing the following objectives:

- methodologies on assessment of environmental effects,
- analyses of necessary and available data,
- overview of international studies/literature,
- analyses of current knowledge and future challenges,
- overview of key actors, stakeholders and their involvement,
- communication strategies to stakeholders, and
- summarizing further R&D demand.

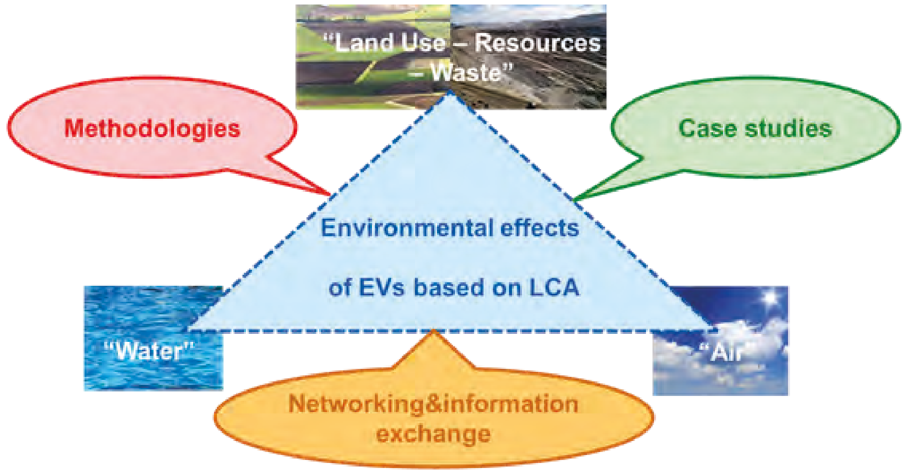

Figure 2: Working method in Task 30

RESULTS

The results of the workshop on impact assessment and the dissemination activities are described.

Workshop

The workshop "Overall Environmental Assessment of EVs – From Inventory Analysis to Impact Assessment" took place on October 13 and 14, 2021 virtually hosted and organized by IREC (Catalonia Institute for Energy Research) in Barcelona/Spain.

The aim of the expert workshop was to present, discuss and conclude on state of the art and experiences on the overall assessment of environmental effects in LCA of electric vehicles – from "Inventory Analysis to Impact Assessment of EVs".

Impact assessment

Life Cycle Assessment (LCA) is a methodology to estimate environmental effects of a product or service along the whole life cycle – from production, use and end of life treatment. There is an international consensus that the environmental effects can only be analysed and assessed on the basis of LCA.

The Task 30 "Assessment of Environmental Effects of Electric Vehicles" (2016 – 2022) in the Technology Collaboration Program (TCP) of the International Energy Agency (IEA) works on the LCA of electric vehicles in comparison to vehicles using fossil and renewable fuels.

The four phases of an LCA (according to ISO 14,044) are

1) Goal and Scope Definition
2) Inventory analysis
3) Impact Assessment and
4) Interpretation.

The focus of the expert workshop of Task 30 was to analyse and assess different Impact Assessment methodologies of battery electric vehicles (BEV) and conventional vehicles with an internal combustion engine (ICE). Based on the inventory analysis of elementary and physical flows in the Life Cycle Assessment (LCA), different impact categories beyond global warming and primary energy consumption are relevant. The way from Inventory Analysis to Impact Assessment is via mid- and end-point indicators. In the workshop the status, the future perspectives and limitations of the Impact Assessment and its impact categories relevant for LCA of vehicles were presented by LCA experts and discussed within the participants.

In Figure 3, the procedure from Inventory Analysis to the Impact Assessment in LCA is shown, where in step 1 the mid-point indicators and in step 2 the possible end-point indicators are assessed. In step 1 and step 2 the different impact assessment methodologies are applied.

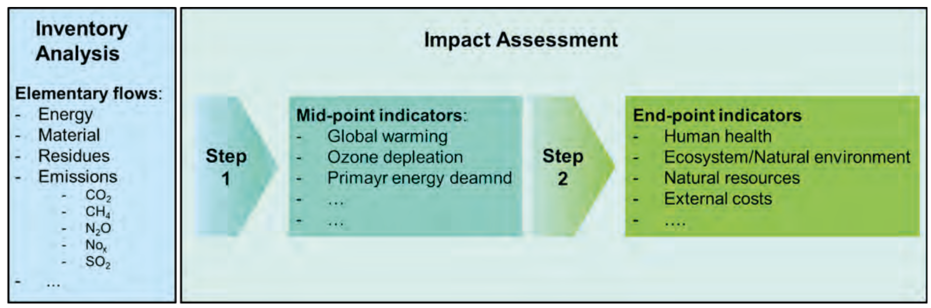

Figure 3: From Inventory Analysis to the Impact Assessment in LCA

Within the workshop the different mid- and end-point indicators with their assessment methodology were presented and discussed.

With regard to the geographical scope of the different impacts, the mid-point indicators are grouped for global, regional and local impacts. The mid-point indicators on these geographical scopes collected in the workshop were:

GLOBAL

- Climate change
- Ozone depletion
- Primary energy use (consumption) (fossil and renewable)
- Resource use, minerals, and metals
- Water footprint (based on inventory level method)
- Land use (focus on inventory data)

REGIONAL

- Acidification
- Photochemical ozone formation
- Smog formation
- Eutrophication, terrestrial, freshwater, and marine
- Ionising radiation

LOCAL

- Human toxicity, cancer, and non-cancer
- Particulate matter
- Land use
- Water scarcity
- Biodiversity
- Ecotoxicity, freshwater aquatic, marine aquatic, and terrestrial

Water and land use were allocated to the global and regional levels. While at the global level, the results of inventory analysis are mainly relevant, at the local level, a very distinctive methodology could be applied for local impact assessment based on very local data.

The end-point indicators, which are always assessed on a global scale, collected in the workshop are:

PROTECTION AREAS

- Human health
- Ecosystem health
- Resource availability

EXTERNAL COSTS.

- A distinction between mid- and end-point indicators is made.

Mid-point indicators

The brief description of global mid-point indicators are:

CLIMATE CHANGE:

- Radiative forcing as global warming potential - GWP 100 (kg CO2-eq) Global Warming Potential kg CO2-eq
- Increase in the average global temperature resulting from greenhouse gas emissions

OZONE DEPLETION:

- Ozone depletion potential – ODP (kg CFC-11-eq)
- Depletion of the stratospheric ozone layer protecting from hazardous ultraviolet radiation

PRIMARY ENERGY USE (CONSUMPTION) (FOSSIL AND RENEWABLE):

- o Use of fossil, renewable and nuclear primary energy resources (MJ)
- o Depletion/use of energy resources and deprivation for future generations

RESOURCE USE MINERALS AND METALS:

- Abiotic resource depletion – ADP ultimate reserves (kg Sb-eq)
- Depletion of mineral and metal resources and deprivation for future generations

WATER FOOTPRINT:

- Amount of water consumed (m^3)
- Amount and type of water used

LAND USE:

- Occupied land (m^2)
- Amount and type of land occupied over a certain time.
- Amount and type of land transformed

The brief description of regional mid-point indicators are:

ACIDIFICATION:

- Accumulated Exceedance - AE (mol H+ eq) or kg SO2-eq
- Acidification from air, water, and soil emissions (primarily sulphur components) mainly due to combustion

PHOTOCHEMICAL OZONE FORMATION, HUMAN HEALTH:
- Tropospheric ozone concentration increase (kg NMVOC eq (ethen –eq C2H4-eq)
- Potential of harmful tropospheric ozone formation ("summer smog") from air emissions

SMOG FORMATION:
- Formation of intensive air pollution with decreasing visibility deriving from combustion processes
- Potential of smog formation ("winter smog") from air emissions

EUTROPHICATION, TERRESTRIAL, FRESHWATER, AND MARINE:
- Accumulated exceedance – AE (mol N eq)
- Fraction of nutrients reaching freshwater/marine end compartments (kg N eq)
- Eutrophication and potential terrestrial impact caused by nitrogen and phosphorus emissions mainly due to fertilizer, combustion, sewage systems

IONISING RADIATION, HUMAN HEALTH:
- Human exposure efficiency relative to U – 235 (kBq U-235 eq)
- Impact of exposure to ionising radiation on human health

The brief description of local mid-point indicators are:

HUMAN TOXICITY, CANCER, AND NON-CANCER
- Comparative toxic unit for humans on (non-)cancer (CTUh)
- Potential impacts on human health via ingestion and inhalation routes. Contact and direct exposure not considered

PARTICULATE MATTER
- Impact on human health (disease incident)
- Impact on human health caused by particulate matter emissions and its precursors (e.g. sulphur and nitrogen oxides)

LAND USE
- Soil quality index, representing the aggregated impact of land use on: biotic production, erosion resistance, mechanical filtration, groundwater replenishment
- Transformation and use of land for agriculture, roads, housing, mining or other purposes. The impact can include loss of species, organic matter, soil filtration capacity, permeability

WATER SCARCITY
- Weighted user deprivation potential (m^3 world eq)
- Depletion of available water depending on local water scarcity and water needs for human activities and ecosystem integrity

BIODIVERSITY
- Impacts on biodiversity
- Various methods under development that can be operable and in line with current life cycle inventory phase

Ecotoxicity is also a regional impact, which could be an aspect of water and land use as well as biodiversity

END-POINT INDICATORS

The discussed possible end-point indicators are
- Protection areas and
- External costs

The Protection areas are split in

- Human health, which is measured in DALYs - Disability-Adjusted Life Years or Disease-Adjusted Life Years caused by the various impacts

- Ecosystem health, which is measured in PDFm2yr Potentially Disappeared Fraction of species per square meter per year, caused by the various impacts

- Resource availability, which is measured in MJ, covering mainly primary energy resources

The External costs are measured in € (or $). The External cost assesses the damage costs caused by the various impacts, e.g., on human health, ecosystem, and infrastructure. Main damage costs are caused by climate change impacts, regional air pollution and land use.

Assessment methodologies for local and regional impacts

The following most relevant assessment methodologies for regional and local impacts were identified.

HUMAN TOXICITY POTENTIAL

The Human Toxicity Potential (HTP) is a measure of the impacts on human health. The characterisation factors describe the fate, exposure, and effects of toxic substances over an infinite time horizon.

Since 2005, a comprehensive comparison of the existing methods was initiated by the UNEP-SETAC Life Cycle Initiative. The consensus model USEtox is now recommended as the “best” available method by UNEP-SETAC (http://usetox.org), and also recommended by EC-JRC for Product Environmental Footprints for human toxicity potential. In USEtox, a distinction is made between “interim” and “recommended” characterisation factors (CF). This reflects the different level of reliability of the calculations. CFs for metals are classified as “interim” due to high uncertainty on fate and exposure:

- The mid-point CFs units for HTP are in “Comparative Toxic Unit for Human Health” (CTUh), which estimates the increase in morbidity in the total human population per unit mass of a chemical emitted (i.e., cases per kilogram). Separate “cancer” and “non-cancer” CTUh are provided, but both have default equal weighting, in lack of more precise insights

- End-point CFs is “Disability-Adjusted Life Years” or “Disease-Adjusted Life Years” (DALY), taking into account the years lost to premature death and expressing the reduced quality of life due to illness in years as well, are also optionally provided. These entail further assumptions and uncertainty, and are not ISO-compliant for all “comparative assertions intended for public disclosure” (ISO 14,044).

Another methodology developed for Human Health, e.g., particulate potential (HHPP), is TRACI - Tool for the Reduction and Assessment of Chemical and other environmental Impacts (https://www.epa.gov/chemical-research/tool-reduction-and-assessment-chemicals-and-other-environmental-impacts-traci)

ABIOTIC DEPLETION POTENTIAL

The Abiotic Depletion Potential - Minerals & Metals (ADP_MM) concerns the extraction of scarce minerals. Values are determined for each extraction of minerals based on the remaining reserves and rate of extraction. AD methods mainly differ in terms of time horizon (e.g., focus on long-term depletion potential vs. short-term supply risk), and associated assumptions on reserve bases:

- The CML ADP [ultimate reserves] uses current extraction rates and assumes stock estimates = total crustal contents
    - Total crustal content is chosen as the best available proxy for “ultimately extractable” reserve, since the latter is a moving target that depends on unknown future technological developments
    - Mid-point CFs are expressed in terms of kg Antimony equivalent (Sb-equivalent)
    - Method originally developed in 1995, then CFs updated in 2002 and 2019.
    - This method is “recommended” by UNEP/SETAC Life Cycle Initiative, and by EC-JRC

- ADP [economic reserves] alternatively assumes stock estimates, those that are economically extractable at present
    - Mid-point CFs are still expressed in terms of kg (Sb-equivalent).
    - This method better highlights the more imminent pressure on resource availability
    - But, it suffers from two main weaknesses:
        - Anthropogenic stocks (e.g., secondary sources) are excluded
        - Economic reserve estimates tend to increase over time, leading to potential underestimation of depletion threat
    - This method is only “suggested” but not officially “recommended” (a much weaker endorsement)

WATER

To assess water related impacts two main methodologies are relevant:

- Water Footprint and
- Water Scarcity

The Water Footprint Standard is an inventory-level method (https://waterfootprint.org/en/resources/publications/water-footprint-assessment-manual-global-standard/).

In the Water Footprint the water withdrawal is analysed and classified in:

- Off stream water use
    - Consumptive use and
        - Green water: evaporative from crops/forestry
        - Blue water: non-evaporative run-off

        - Grey water: additional water required to dilute pollutants to water quality standards
    - Degradative use, released as polluted water

- In stream water use, released as unpolluted water

For Water Scarcity there are two impact assessment methodologies
- Water Stress Index (WSI) and
- Available Water Remaining (AWARE)

The main aspects of these two impact assessment methodologies are:

- Water Stress Index (WSI)
    - Water Stress Index is typically defined as the relationship between total water use and water availability. The closer water use is to water supply, the more likely stress will occur in natural and human systems.
    - Regionalised mid-point characterization model based on withdrawal-to-availability ratio
    - WSI indicates the portion of WU [consumptive] that deprives other users of freshwater
    - Further converted to end-point indicators for Ecosystem Quality (EQ) and Human Health (HH), the latter based on competition with irrigation
    - This indicator has been used by the United Nations and others.

- Available Water Remaining (AWaRe)
    - Regionalised mid-point characterization model based on withdrawal-to-availability ratio
    - New consensus method of UNEP/SETAC working group on water use in LCA (WULCA)
    - Suggested by EC-JRC as new standard impact assessment method for water use in PEF
    - WaterS is an indicator from the AWARE characterisation model that provides an assessment for water consumption. Units for scarcity-adjusted water use are in m3 world eq

BIODIVERSITY
Biodiversity is also much related to land use aspects. The impact assessment methodologies are therefore very complex and still under development e.g.:

- Ongoing efforts of the JRC within dedicated working groups.

- JRC is exploring LCIA methods and approaches addressing impact on biodiversity to be potentially integrated in the EF method in the future

- Currently, operational and novel methods addressing impact on biodiversity at the midpoint and endpoint (that take into account different midpoint impacts such as Climate Change, Land Use, etc.) are under test by the JRC

- Key aspect is to judge how these methods can be operable and in line with current inventory phase

SELECTION OF INDICATORS IN LCA FOR EVS AND ICES

Life Cycle Assessment is a method to analyse and assess a system from cradle to grave for product and services. LCA as a system assessment method addresses environmental impacts best on a global scale like global warming or resource use. The assessment of regional and local environmental impacts like acidification, human toxicity and biodiversity are depending very much on site-specific local conditions. So, an inclusion of regional and local impact categories needs a very site-specific inventory in LCA, e.g., in combination with GIS (Geographical information System).

Due to the high need of site-specific data and/or lacking these data, the regional and local impacts are very difficult to be addressed in practice by LCA or EVs and conventional ICEs today. Further essential developments are needed to cover these impacts in future.

It is also argued that other methodologies than LCA can address these regional and local environmental impact better, e.g., biodiversity is mainly relevant in agricultural and forestry systems, human toxicity is relevant for quality of life and living conditions.

Due to the methodological complexity and uncertainty, the practical addressing and calculation of "end point indicators" is not recommended for LCA of electric vehicles and conventional vehicles.

The main relevant impacts with current state of impact assessment methodologies using available and robust inventory data in LCA are mainly for global impact categories.

The main global impact categories for transportation systems are:

- Climate change
- Primary energy use (consumption) (fossil and renewable)
- Resource use minerals and metals
- Water footprint (inventory level)
- Ozone depletion
- Land use (inventory level)

FRAMEWORK

Taking these six identified global impacts for EVs into account, there are some recommendations concluded for current and future LCA practical application. The recommendations are split into the following for global impact assessment of EVs in comparison to other vehicles:

- current minimum requirements and
- future advanced requirements

For all considered impacts of course the goal and scope of the LCA is essential. The results on the considered global impact categories should be documented and communicated not only for the total value but also for the three main phases in the life cycle of a transportation system:

- Production
    - vehicle
    - energy/battery storage

- Operation
  - fuel/energy supply
  - fuel use
  - maintenance

- End of life
  - recycling and/or reuse
  - substitution of secondary material

The main influencing parameters on the global impacts should be identified and described.

CURRENT MINIMUM REQUIREMENTS

The current minimum requirements on LCA for EVs and ICEs should cover Global Warming and Primary Energy Consumption as major relevant global impact categories addressing the key issues of GHG-emissions and energy efficiency.

The following should be considered on these two global impact categories:

- Global Warming:
  - The Global Warming Potential is given in kg CO2-eq100.
  - The individual GHG-gases and their CO2-equivalent factor should be described, e.g. according to IPCC AR; now also biogenic based CH4-emissions have a different equivalent factor than fossil based CH4 (e.g. form coal mining).
  - The contributions (%) of the most relevant individual GHG gases should be documented.

- Primary energy demand:
  - The Primary Energy Demand (PED) is also called Cumulative Energy Demand (CED) or Total Primary Energy (TPE) with analogue meaning
  - Primary energy demand is given in MJ
  - It must be specified if the methodology for the Primary Energy Demand is based on the lower (LHV) or higher heating value (HHV). The difference might be up to 5%, but there is no general agreement on the type of heating value.
  - Beside the total Primary Energy Demand also the share (%) of renewable and fossil and nuclear energy should be described.
  - Optionally it is also useful especially for EVs to identify the major primary energy carriers used, e.g., coal, natural gas, wind, hydro, solar, nuclear.

FUTURE ADVANCED REQUIREMENTS

The future advance requirements for impact assessment address

- Resource use, minerals, and metals
- Water footprint (inventory level)
- Land use
- Ozone depletion

For EVs (incl. batteries) and renewable electricity generation the type and amount of material used in the construction phase becomes more relevant than for conventional vehicles using raw oil. Therefore, the impact category of "Resource use, mineral and metals" also becomes a more relevant global impact category. Concluding, an advanced requirement for LCA should be to calculate the amount of material in the inventory analysis especially for the most relevant materials like Cu, Li, Co, Ni, Mn, and others. Based on this inventory the resource use should be assessed on the basis of kg Sb-eq. and giving the main contributions from single minerals or metals.

Water issues are also relevant, especially for mining activities, Lithium extraction and hydro power. So, on a global scale the Water Footprint using the inventory-based methodology should be assessed in future LCA of EVs and ICEs.

Also, land use aspects are relevant for mining of raw materials as well as for renewable electricity production. As a next step in LCA of EVs the amount of land or land occupation over time should be analysed in the inventory phase by at least differentiation on the type of land: agriculture, forestry, infrastructure, industrial area, or any other type of land.

The impact category "Ozone Depletion" can easily be addressed in LCA of EVs and ICEs, but seems currently of lower relevance for transportation systems, except from losses of fluids from cooling systems or their end-of-life treatment.

Conclusion and outlook

These global indicators also cover and address aspects of the two most relevant environmental aspects currently under public and political agenda e.g., GreenDeal:

- "Climate neutrality" and
- "Circularity".

But as these aspects are relevant in a dynamic system perspective e.g., recycling to secondary material, further methodological developments are necessary to integrate them in LCA.

Considering current international LCAs on EVs in comparison to ICE it becomes obvious that Global Warming and Primary Energy Consumption are a minimum requirement and state of the art in Impact assessment. LCAs disregarding one of these two impacts are too limited or misleading in their conclusions and interpretations.

It is expected that the other global impacts - Resource Use, Water Footprint and Land Use – will be analysed and assessed in LCA of EVs in future more often, using the rapid international progress made for inventory data.

Considering the local and regional impact categories in LCA further methodological developments, better inventory data and general acceptance are necessary or these environmental impacts (e.g., biodiversity) will be addressed with other methodologies than LCA more adequate in future.

The new IEA HEV TCP Task 46 (2022 – 2024) "LCA of electric Trucks, Buses, 2-Wheelers and other Vehicles" will address these global impact categories further and intends to develop and discuss new approaches to address "Climate Neutrality" and "Circularity" of transportation system in (dynamic) LCA.

Dissemination activities

The dissemination activities were:

PRESENTATIONS

- Climate Friendly Biofuels in Comparison to Other Fuels, Renewables in Transport, Expert Talk, January 21, 2021, online
- LCA Application to Growing EV-Fleets with Increasing Supply of Renewable Electricity – Methodological Aspects and Assessment for GHG Emissions of BEV Introduction in Austria, IEA HEV Task 30 meeting, online, February 3, 2021
- Greenhouse Gas and Energy Balance in the Life Cycle of Passenger Vehicles – Comparing E-Fuels and Electricity; E-Fuels oder Verbrenner-Verbot?, Die Mobilitäts-Politik der EU am Scheideweg, 28.4.2021, online
- GHG-Emissions of Additional Renewable Electricity in Austria and its Consequences on the Introduction of Electric Vehicles in a Dynamic LCA, IEWT 2021, September 9 – 11, 2021, Vienna, Austria
- Life Cycle Analysis of BEV and ICE, SEAI National Energy Research & Policy Conference, November 25, 2021, Ireland
- Renewable Energy for Climate Friendly Lifestyles - Example Mobility Services with Battery Electric Vehicles; for RENEWABLEMEET2022 - International Meet on Renewable and Sustainable Energy March 21-23, 2022, Dubai, UAE
- Scenarios for a Climate Neutral Vehicle Fleet in Austria Using Dynamic LCA, 17. Symposium Energieinnovation, 16.-18. February 2022, Graz, Austria

PUBLICATION

- GHG Emissions and Primary Energy Demand of Vehicle Fleets Based on Dynamic LCA Methodology – Introduction of Electric Vehicles in Austria 2010 – 2050, 13th International Colloquium Fuels, September 15-16, 2021, Esslingen, Germany

POSTER

- Scenarios for a Climate Neutral Passenger Vehicle Fleet in Austria 2040 Using Dynamic LCA, ECO-Mobility – A3PS-Conference 2021, November 18-19, 2021, Vienna, Austria

IEA HEV NEWSLETTER

- Contributions #1, #2 and #3 in 2021

ABSTRACTS SUBMITTED

- Climate Neutrality of Growing Electric Vehicles Fleets (2010 - 2050) in a Dynamic LCA Considering Additional Renewable Electricity: Example Austria; EVS35 Symposium Oslo, Norway, June 11-15, 2022
- Ökobilanz eines e-Bikes im Vergleich zum konventionellen Fahrrad, 13. Österreichischer Radgipfel, 3. - 5. April 2022, Vienna, Austria

NEXT STEPS

The task will be finished in May 2022, after which, the report will be available on the HEV TCP website.

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TASK 34

Batteries

MEMBER COUNTRIES
CANADA
GERMANY
SWEDEN

INTRODUCTION

Task 34 deals with topics related to the chemistry and performance of electrochemical energy storage devices of interest to those working on electric drive vehicles. Electric vehicles are important because they reduce our reliance on petroleum, thereby increasing economic security, and providing an opportunity to improve air quality with increased fuel economy while reducing, or eliminating, tail-pipe emissions. Since batteries account for a significant part of the total cost of electric vehicles (EVs); R&D continues world-wide to develop higher energy density, abuse-tolerant and affordable batteries – i.e., batteries that would cost less, weigh less, last longer, avoid range anxiety, and lead to widespread electrification of the transportation sector.

OBJECTIVES

The goal of Task 34 is to encourage the sharing and dissemination of current information about battery topics of interest to the vehicle community.

WORKING METHOD

The primary focus of this task is on collecting and reporting information on EV battery performance and cost state-of-the-art, and on R&D being conducted worldwide through country-to-country information exchange and public meetings.

RESULTS

Advances in Cobalt-free Materials

BACKGROUND

Currently, lithium-ion batteries contain a substantial amount of cobalt, a critical material that is both expensive (in 2017, average annual cobalt prices more than doubled) and dependent on foreign sources for production.[1] The Democratic Republic of Congo supplies nearly 60% of the world's cobalt with 60% going to China. China is the world's leading producer of refined cobalt and a leading supplier of cobalt imports to the United States[2]; this dependency could become a concern for U.S. end-users.

The growth in demand for lithium-ion batteries for EVs will establish EVs as the largest end-user of cobalt and lithium; and could potentially create a cobalt and lithium supply risk.[3,4,5] Because of the above-listed concerns, DOE has been funding several R&D projects on low-cobalt/no-cobalt cathodes. A couple of recent highlights from this research area are presented below.

A NEW CLASS OF COBALT-FREE OXIDE CATHODES

There is a wide range of structures and electrochemical properties associated with manganese (Mn)-oxides, and Mn is abundant. It has a long history in battery technologies and may have an important role in next-gen cathodes.

An Argonne National Laboratory (ANL) research team recently developed a novel concept for utilizing lithiated Mn-spinel oxides as Li-ion cathode materials. It demonstrated a specific energy higher than most NMC811 materials. The spinel framework offers a robust platform to reversibly cycle lithium in and out of its 3D tunneled structure.

However, low capacities (e.g., 130mAh/g for LiMn2O4) and/or untenable voltages (e.g., 5-volt operation in LiMn1.5Ni0.5O4) hinder their ability to meet practical demands. The team at Argonne revisited the intriguing concept of lithiated spinels, (e.g., Li2Mn2O4), as both stabilizing components of Li-excess cathodes as well as stand-alone electrodes. The study reveals that local atomic arrangements within the new materials dramatically influence macroscopic electrode properties. Starting with a lithiated Co-oxide spinel, the substitution of Co with Al, accompanied by low amounts of disorder among certain crystallographic sites, changed the two-phase lithium insertion/extraction mechanisms of known spinels to a single-phase reaction for the new oxides. The electrodes showed a zero-strain behavior (virtually no expansion/contraction on cycling); with implications for developing solid-state as well as traditional Li-ion cells).

Using this knowledge, a high-capacity, Co-free composition was targeted utilizing a 50/50 mix of Mn and Nickel (Ni). Again, by controlling atomic-level disorder, within an ordered lithiated spinel framework, the team was able to realize a remarkably stable, high-capacity material. Figure 1 shows charge/discharge profiles between 5.0-2.5V of the MnNi electrode, 5mg/cm2. This electrode behaves differently than the high-voltage MnNi spinel, with substantial capacity delivered throughout the voltage window (as opposed to the high-voltage material which primarily delivers capacity at 5V). In addition, the new material showed very low expansion/contraction (<3%) during cycling, giving a stable ~225 mAh/g with little structural fatigue.

These findings, with the large space of relevant parameters (composition/synthesis/site-order/disorder) could potentially provide opportunities for a better designed next-gen, sustainable cathode.

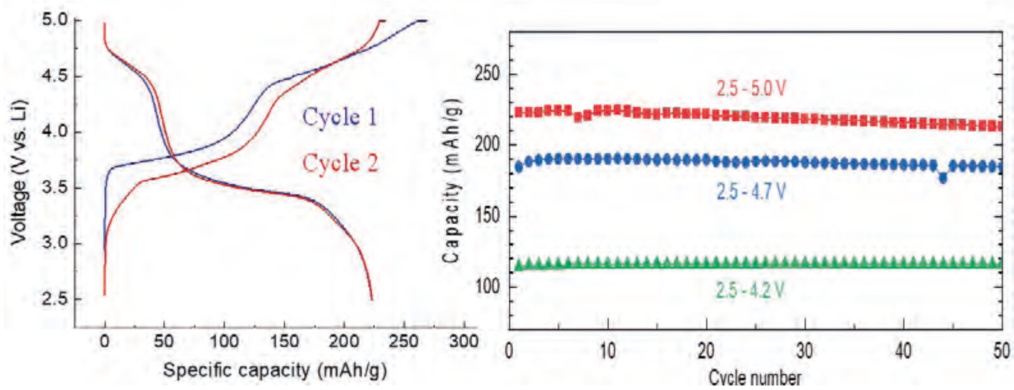

Figure 1: (left) Unique charge/discharge profiles of the novel, lithiated spinel between 5.0-2.5 V. (right) Cycling capacity at three upper cutoff voltages highlighting the stability of the cathode material, electrolyte is 1.2M LiPF6 EC/EMC 3/7 wt%

Source: Argonne National Laboratory).

IMPROVED CYCLING OF COBALT-FREE DISORDERED ROCK-SALT (DRX) CATHODES VIA FLUORINATION

Conventional layered oxide cathodes predominate commercial lithium-ion batteries for high-energy applications. However, they require a large amount of expensive and scarce transition metals (TM) (i.e., Co, Ni).

Recently, Li-excess cation-disordered rock-salts (DRXs) have received significant interest, as they are Co/Ni-free, with abundant sources. The structural flexibility of DRXs enables a wide range of TMs as well as fluorine anions (suitable for high-voltage operation) in the crystal lattice (Figure 2a).

Researchers at Lawrence Berkeley National Laboratory have synthesized a fluoridated Mn-Ti DRX cathode, Li1.2Mn0.6Ti0.2O1.8F0.2, via a solid-state reaction. These Mn and Ti TMs present distinct advantages in cost and sustainability compared to conventional choices (e.g., Co, Ni) in layered and other DRX analogs (Figure 2b). As shown in Figure 2c, Li1.2Mn0.6Ti0.2O1.8F0.2 delivers an initial capacity of 233 mAh/g (comparable to NMC 811) when cycled between 4.8 and 1.5 V, using 1M LiPF6 EC:DMC. Moreover, this material exhibits stable cycling and retains over 90% of capacity after 200 cycles.

This excellent cycling stability is attributed to the partial fluorination of the oxygen lattice, which increases the content of redox-active Mn and facilitates utilization of more reversible Mn redox during electrochemical cycling. This material experiences a local structural rearrangement during early cycles before exhibiting a stable voltage upon extended cycling (Figure 2d, Figure 2e). This early change in voltage profile may present an implementation challenge and will be investigated in future studies. These advancements show a great promise for developing cost-effective DRX cathodes with enhanced capacity and retention for high-energy Li-ion batteries.

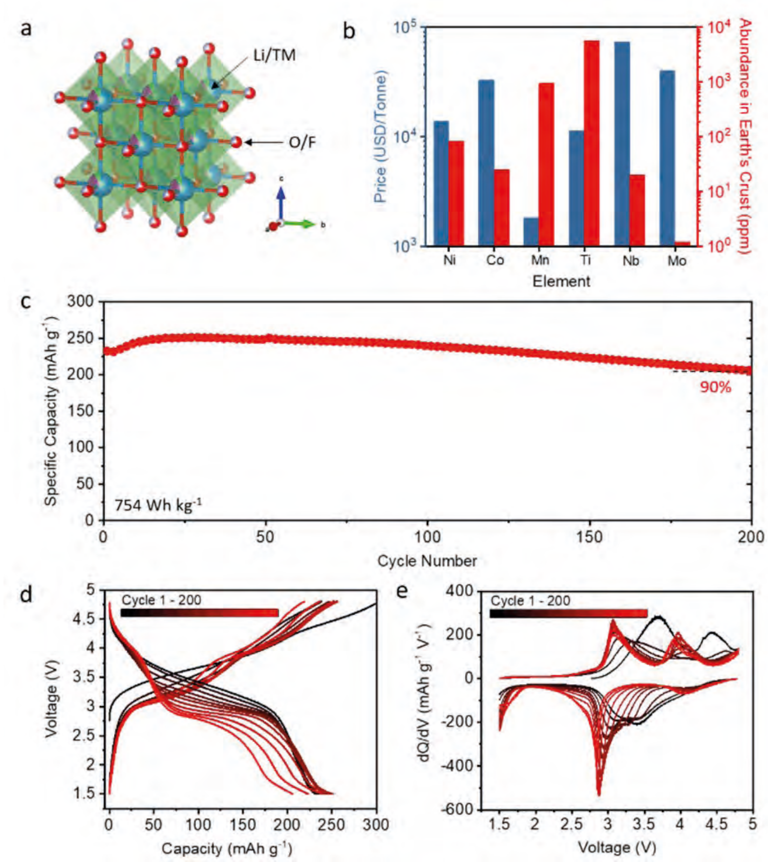

Figure 2: Battery performance of a highly fluorinated DRX, Li1.2Mn0.6Ti0.2O1.8F0.2. (a) Crystal structure, (b) price and abundance of selected transition metals, (c) specific capacity, (d) voltage profiles, and (e) differential capacity plot. DRX cell is cycled at 16 mA g-1 within 4.8 and 1.5 V

Source: Lawrence Berkeley National Laboratory

Advances in Lithium Battery Recycling

BACKGROUND

There are strong reasons to recycle Li-ion batteries. Materials recovered from recycling can be used to make new batteries, reducing costs. Recycling would reduce the quantity of material going into landfills, avoiding contamination of soil and groundwater. More recycling would also mean less use of virgin material, and less environmental harm associated with it as well as a slower depletion of these materials.

There are also political costs and downsides due to the use of rare-earth materials that recycling could help address.

AQUEOUS SEQUENTIAL SEPARATION OF ELECTRODES FROM LITHIUM-ION BATTERIES

The direct recycling of lithium-ion (Li-ion) batteries aims to recover the valuable components from its cells, including black mass (e.g., active cathode materials and graphite), copper (Cu) foils, and aluminum (Al) foil current collectors. Electrode materials are tightly adhered to metal current collectors through binders, making the recovery a challenge – which gets tougher when the cathode and the anode are mixed-up after shredding. To reclaim valuable cathode materials with high purity, it is necessary to separate the electrode materials from current collectors, and the electrodes themselves.

Scientists at Oak Ridge National Laboratory (ORNL), as part of the ReCell program, developed a low-cost and two-step process to recover electrode materials and current collectors from spent Li-ion batteries. In the first step, a solution containing an aqueous potassium phosphate buffer solution at a constant pH of 5.0 is selected to delaminate anode films from copper foils at room temperature and prevent Al from dissolution (Figure 3). The graphite is separated, but the cathode films stay intact due to strong adhesion of the binder to the Al foil.

In the second step, a surfactant (sodium dodecyl sulfate, TritonTM X-100) is added to the mix of copper foils and cathode electrodes in the presence of the buffer solution to peel off the cathode films from the Al foil by both reducing the surface energy and weakening the adhesion (Figure 3). The cathode films and current collectors (Al and Cu) then get separated due to the difference of density.

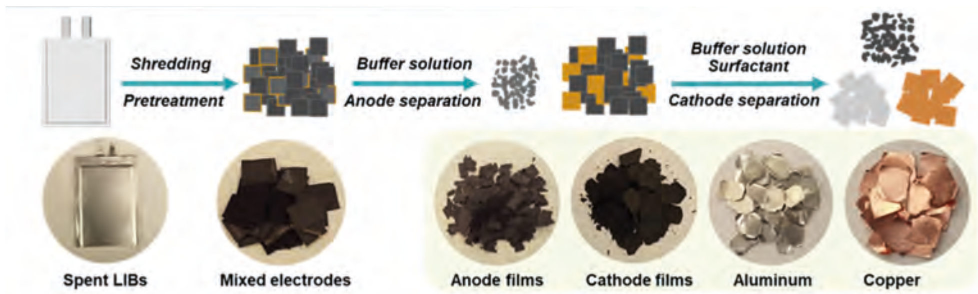

Figure 3: Flowchart of the aqueous sequential separation process to recover cathode films, anode films, copper, and aluminum foils

Source: Oak Ridge National Laboratory

LITHIUM BATTERY RECYCLING PRIZE (PHASE III PROGRESS)

In an effort to develop a well-distributed, efficient, and profitable infrastructure for recycling lithium-ion batteries and innovative solutions to challenges associated with collection, storage, and transportation of spent or discarded lithium-ion batteries, DOE established a $5.5 Million Battery Recycling Prize.[6] Its goal is to develop innovative business and technology strategies to potentially capture 90% of all lithium-based battery technologies (consumer electronics, stationary, and transportation applications) and to improve collection, sorting, storing, and transportation of lithium-based batteries.

The National Renewable Energy Laboratory (NREL) was selected as the administrator for the Prize. In Phase I, 15 entries adequately met the criteria for innovativeness, impact, feasibility, and technical approach outlined in the Prize Rules. Of them, in Phase II, seven winners were announced to further the development of concepts.

The Phase III Rules were released on January 13, 2021, via a DOE press release.[7] On January 27, 2021, the NREL Prize Administrator hosted a Phase III Welcome Meeting for all participating teams and the pre-identified voucher service providers. Each team met directly with the Prize Administrator and DOE support to review feedback from their Phase II final submissions in a one-on-one meeting. The Prize Administrator continued to work closely with each team to help develop a statement of work for the voucher funds in Phase III. The NREL Prize Administrator provided a comprehensive communications toolkit to the participants.

Mid-way through 2021, the seven teams were required to submit a Phase III Progress Update. A panel of four reviewers reviewed the Progress Updates and provided feedback as they worked toward the Phase III Final Submission Requirements. The NREL Prize Administration Team worked closely with the review panel to compile feedback shared with the participating teams.

LITHIUM METAL BATTERY TECHNOLOGY

BACKGROUND

Lithium (Li) metal batteries offer the potential for significant increases in energy density that could enable larger scale adoption of electric vehicles. However, it is not yet possible to build high energy density lithium metal batteries with long lifetimes (>1,000 cycles) due to the reactivity of Li metal with electrolytes. If specific failure mechanisms of Li metal batteries can be identified, this will help efforts to potentially increase the lifetime of Li metal batteries.

BALANCING INTERFACIAL REACTIONS FOR LONG CYCLE LIFE IN LI METAL BATTERIES

The Battery500 Consortium[8] developed a novel high-performance electrolyte, an optimized electrode architecture and the cell design to balance the electrochemical and chemical (side) reactions in high-energy Li metal cells, achieving more than 600 cycles in prototype 350 Wh/kg pouch cells (2 Ah) (Figure 4).

Researchers discovered that by reducing the thickness of Li metal foil anodes to 20 µm from 100 µm in 350Wh/kg pouch cells (Figure 4b-Figure 4d), both improves cycle life and mitigates the steep capacity drop near the end of cycle life (caused by electrolyte dry-out). When Li metal makes contact with the electrolyte, a passivation film or solid electrolyte interphase (SEI) layer forms due to its high reactivity with electrolyte. Ideally, the insulating SEI layer stops further reactions or “corrosion” of Li metal in the electrolyte while still allowing Li+ transport. However, the formation of SEI layers also consumes electrolyte.

The team theorized that there are two different SEI layers formed within cycled Li anodes, wet and dry. “Wet SEI” (Figure 4a) is formed inside shallow channels or pores of Li metal where contact is retained between the liquid electrolyte and the Li. It supports cell cycling. “Dry SEI” (Figure 4a) forms when no liquid electrolyte is left, often in the deep and narrow pores of SEI-covered Li present in thicker strips. These regions subsequently smother further electrochemical reactions and lead to “cell death”. The thicker the Li metal, the deeper the pores/channels formed.

The amount of electrolyte is extremely limited in real batteries (20-30 times less than in coin cells), and easily depleted in forming dry SEI layers. Thus, optimization of Li metal thickness is critical to extend the lifespan of Li metal batteries.

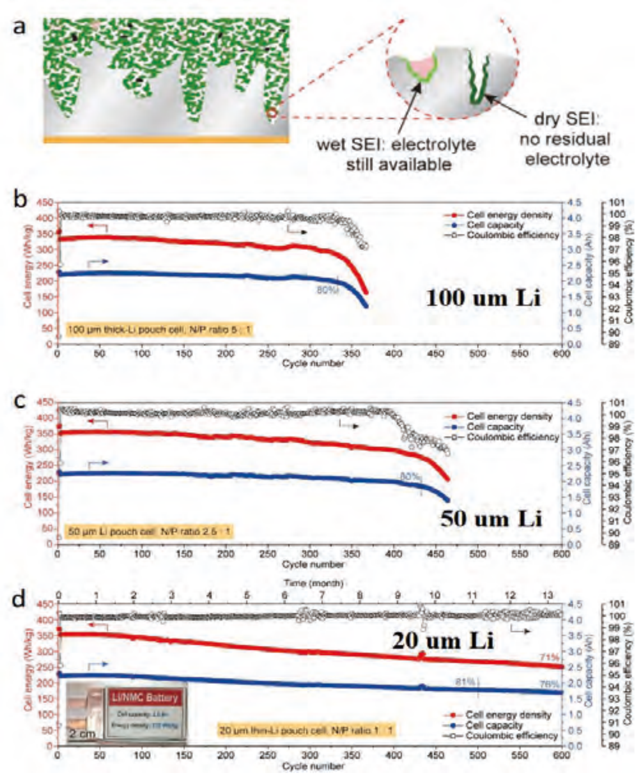

Figure 4: 350 Wh/kg pouch cells achieve more than 600 cycles in research from the Battery500 Consortium. (a) Illustration of wet and dry SEI layers in lithium metal anode. (b)-(d) Cycling performances of 350 Wh/kg lithium metal pouch cells using 100, 50 and 20 μm lithium foils as the anodes, respectively

Source: Pacific Northwest National Laboratory

HIGH-ENERGY LATERAL MAPPING STUDIES OF INHOMOGENEITY AND FAILURE MECHANISMS IN POUCH CELLS

Traditional electrochemical testing methods for determining battery failure cannot determine the failure mode or its location. To better understand failure mechanisms, Brookhaven National Laboratory (BNL) researchers developed new X-ray diffraction methods using the National Synchrotron Light Source II to map position-dependent variations in an end-of-life battery cathode.

The high-energy X-rays readily penetrate cells, allowing industrially relevant pouch cells to be studied. A single cathode layer extracted from a high-energy density Li metal pouch cell was subjected to ~200 cycles (Figure 5a) and then fully discharged. The cell energy dropped below 80% of its starting value after ~175 cycles (considered nominal cell failure) though much of the lost capacity could be recovered by cycling at a lower rate. In mapping experiments (Figure 5b), three hot spots were found in which the cathode state of charge (SOC) was much higher than average, indicating that these three regions were electrochemically isolated. The non-edge spots formed where the cathode amount was about 5% lower than average, indicating that small manufacturing problems in cathode films can lead to early cell failure.

Based on various considerations, it was conclusively determined that the cells failed due to depletion of the electrolyte (through reaction with Li metal) which transports ions between the electrodes. Further mapping studies on a series of coin cell cathodes allowed the electrochemical signatures of this and two other failure modes (loss of Li inventory and impedance rise), thus providing a simple new method to determine how the cell failure takes place.

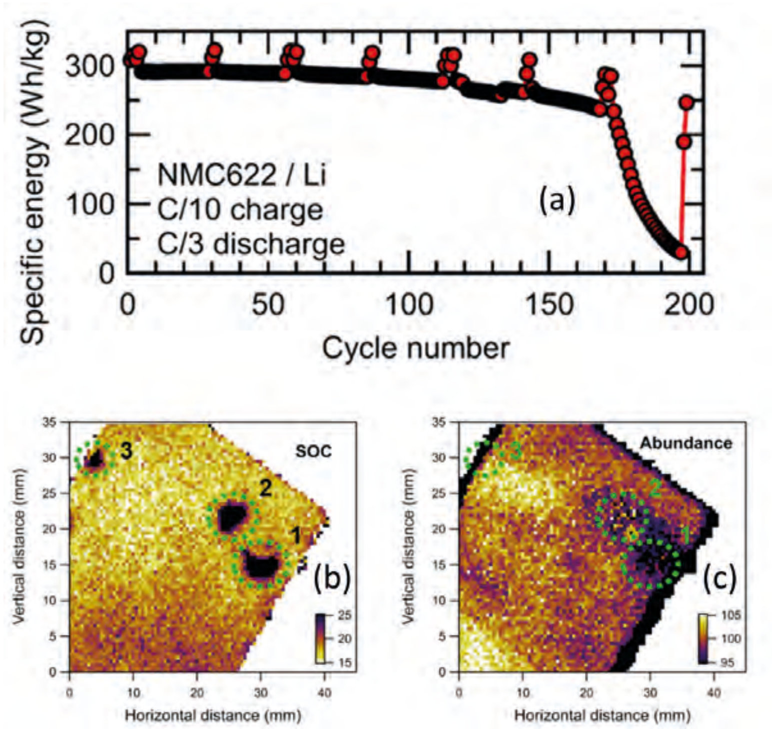

Figure 5: (a) Decay of cell energy during cycling. After every 25 cycles, cell was tested at a very slow rate (C/25) producing spikes of higher capacity. For this cell cycled to failure, maps of (b) the local state of charge and (c) the relative abundance of the NMC cathode were collected, allowing three hot spots (1 – 3) with poor performance to be identified

Source: Brookhaven National Laboratory

NEXT STEPS

The OA, in conjunction with other colleagues in the field, is planning the next discussion meeting. The schedule for this meeting is not yet decided. The OA is working with representatives from the member countries to identify topics and locations for future meetings.

FOR FURTHER INFORMATION, PLEASE CONTACT THE OPERATING AGENT:

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TASK 35

Fuel Cell Electric Vehicles

MEMBER COUNTRIES
REPUBLIC OF KOREA
AUSTRIA

INTRODUCTION

Task 35 Fuel Cell Electric Vehicles of the IEA TCP Hybrid and Electric Vehicles" (HEV) aims at supporting a broader commercialization, acceptance, and a further development of fuel cell electric vehicles (FCVs) by collecting and sharing pre-competitive information, exchange about framing conditions, best practices, and ideas, how to develop the market conditions and mobility concepts further. Task 35 looks at light duty electric vehicles (LDEV) for passenger transport, which are either classified as L-category vehicles, Kei cars, Micro- or subcompact FCVs.

Hydrogen powers fuel cell electric vehicles (FCEVs). They are more efficient than traditional internal combustion engine vehicles and emit no tailpipe emissions—only water vapor and warm air. FCEVs and the hydrogen infrastructure needed to fuel them are still in the early stages of development.

FCEVs use a propulsion system similar to that of electric vehicles, in which hydrogen energy is converted to electricity by the fuel cell. These vehicles, unlike conventional internal combustion engine vehicles, emit no harmful tailpipe emissions.

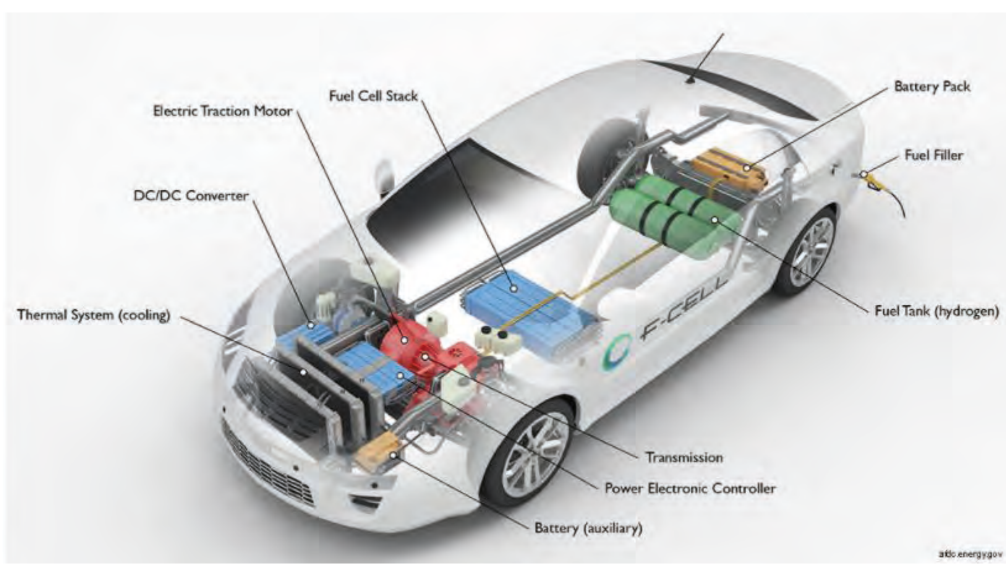


Figure 1: Components of a FCEV
Source: afdc.energy.gov

OBJECTIVE

The task addressed many fields of interest in FCV. Areas considered were broad as the task got underway and narrowed in focus as meetings progressed. Task objectives included the following:

- To analyze the technology for FCVs and hydrogen stations
- To disseminate policy of FCVs and hydrogen stations.
- To share the information of the related technology among the stakeholders through workshops and conferences.
- Documentation and dissemination related to several topics such as: FCVs concepts (Technologies, prospects, and research needs); Hydrogen stations for FCVs concepts (Technologies, prospects, and research needs); and market condition for FCVs and hydrogen stations (international differences and best practices)

WORKING METHOD

The main approach of Task 35 is to collect and exchange information, opinions, and concerns in workshops and to disseminate the results amongst stakeholders and policymakers. Three major topics are distinguished:

- FCVs concepts: Technologies, prospects, and research needs.
- Hydrogen station for FCVs concepts: Technologies, prospects, and research needs
- Market condition for FCVs and hydrogen station: international differences and best practices.

The workshops aim to attract professionals from research, enterprises, and policy makers, depending on the individual topics. An international survey distributed to a wider audience complements the workshops. Major insights and results, together with other findings from desktop research, will be published at conferences and in scientific journals.

Participation is free of charge for experts in the field from universities, research organizations, and public authorities as representatives from IEA HEV-TCP countries. In-kind, contributions are expected. For industry participation, a sponsoring concept is available. Participation in workshops is by invitation only. Please contact the Operating Agent or the respective HEV-TCP country representative.

RESULT

What is an FCEV?

Fuel cell electric vehicles (FCEVs) are powered by hydrogen. They are more efficient than conventional internal combustion engine vehicles and produce no tailpipe emissions—they only emit water vapor and warm air. FCEVs and the hydrogen infrastructure to fuel them are in the early stages of implementation.

FCEVs use a fuel cell to directly convert the chemical energy in hydrogen and oxygen into electrical energy. A fuel cell is distinct from both a rechargeable (or secondary) storage battery, such as that found in BEVs, and a heat engine, though it is more similar to the secondary battery than the heat engine. The main difference between fuel cells and batteries is that in a battery, the electricity-producing reactants are regenerated in the battery by the charging process, whereas in a fuel cell, the electricity-producing reactants are continuously supplied from sources external to the fuel cell itself: oxygen from the air and hydrogen from a separate onboard storage tank.

During the vehicle design process, the vehicle manufacturer defines the power of the vehicle by the size of the electric motor(s) that receives electric power from the appropriately sized fuel cell and battery combination. Although automakers could design an FCEV with plug-in capabilities to charge the battery, most FCEVs today use the battery for recapturing braking energy, providing extra power during short acceleration events, and to smooth out the power delivered from the fuel cell with the option to idle or turn off the fuel cell during low power needs.

As shown in Figure 1, below are some of the components of a hydrogen fuel cell electric car.

a. Battery (auxiliary): In an electric drive vehicle, the low-voltage auxiliary battery provides electricity to start the car before the traction battery is engaged; it also powers vehicle accessories.

b. Battery pack: This high-voltage battery stores energy generated from regenerative braking and provides supplemental power to the electric traction motor.

c. DC/DC converter: This device converts higher-voltage DC power from the traction battery pack to the lower-voltage DC power needed to run vehicle accessories and recharge the auxiliary battery.

d. Electric traction motor (FCEV): Using power from the fuel cell and the traction battery pack, this motor drives the vehicle's wheels. Some vehicles use motor generators that perform both the drive and regeneration functions.

e. Fuel cell stack: An assembly of individual membrane electrodes that use hydrogen and oxygen to produce electricity.

f. Fuel filler: A nozzle from a fuel dispenser attaches to the receptacle on the vehicle to fill the tank.

g. Fuel tank (hydrogen): Stores hydrogen gas on board the vehicle until it's needed by the fuel cell.

h. Power electronics controller (FCEV): This unit manages the flow of electrical energy delivered by the fuel cell and the traction battery, controlling the speed of the electric traction motor and the torque it produces.

i. Thermal system (cooling) - (FCEV): This system maintains a proper operating temperature range of the fuel cell, electric motor, power electronics, and other components.

j. Transmission (electric): The transmission transfers mechanical power from the electric traction motor to drive the wheels.

Fuel cell vehicles (FCVs) have the potential to significantly reduce our dependence on fossil oil and lower harmful emissions that contribute to climate change. FCVs run on hydrogen gas rather than gasoline and emit no harmful tailpipe emissions. Several challenges must be overcome for them to be competitive with conventional vehicles, but their potential benefits are substantial. FCVs run on hydrogen can be represented as one of the sustainable mobility modes.

The interest in hydrogen as an alternative fuel under stems from its ability to power fuel cells in zero-emission electric vehicles, its potential for domestic production, and the fuel cell's potential for high efficiency and easier to overcome the distance anxiety unlike electric vehicles. In fact, a fuel cell coupled with an electric motor is two to three times more efficient than an internal combustion engine running on gasoline. However, nowadays, FCVs still have limitations because only a few hydrogen stations are available. Then, the major manufacturers, such as Hyundai and Toyota, for example, are currently offering their production fuel cell electric vehicles for sale or lease to customers living in markets where hydrogen fuel is available. Therefore, it will be very useful to look in detail at FCVs as a sustainable mobility representative and its energy infrastructure, such as its technology concepts, prospects, research needs, market condition, and hydrogen stations (international differences and best practices).

The technology for FCVs and hydrogen stations

HYDROGEN STATION CONCEPT

Task 35 participants held two workshops per year, with each workshop focused on a particular aspect of FCVs and hydrogen stations. Participation is free of charge for experts in the field from universities, research organizations, and public authorities as representatives from IEA HEV-TCP countries. In-kind contributions are expected. For industry participation, a sponsoring concept is available. Participation in workshops is by invitation only. Please contact the Operating Agent or the respective HEV-TCP country.

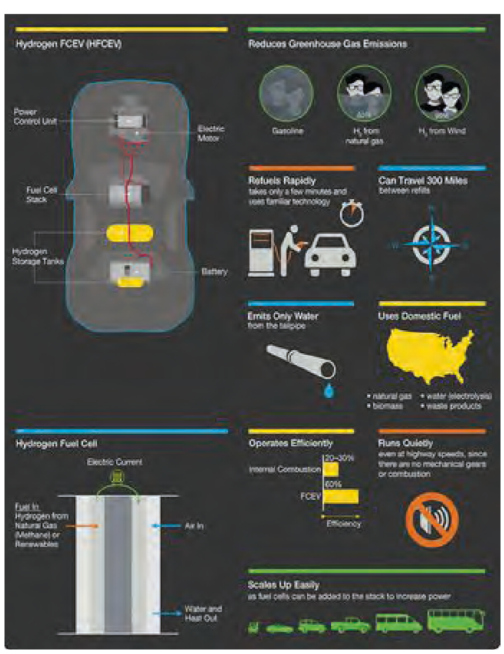


Figure 2: Hydrogen FCEV
Source: compilation sources of IEA, IPHAE,etc

FCEV is powered by electricity generated from the electrochemical reactions between hydrogen dispensed into FCEV hydrogen tanks, and oxygen. Because FCEV is powered by electricity generated from the electrochemical reactions between hydrogen and oxygen, the only byproduct is pure, distilled water.

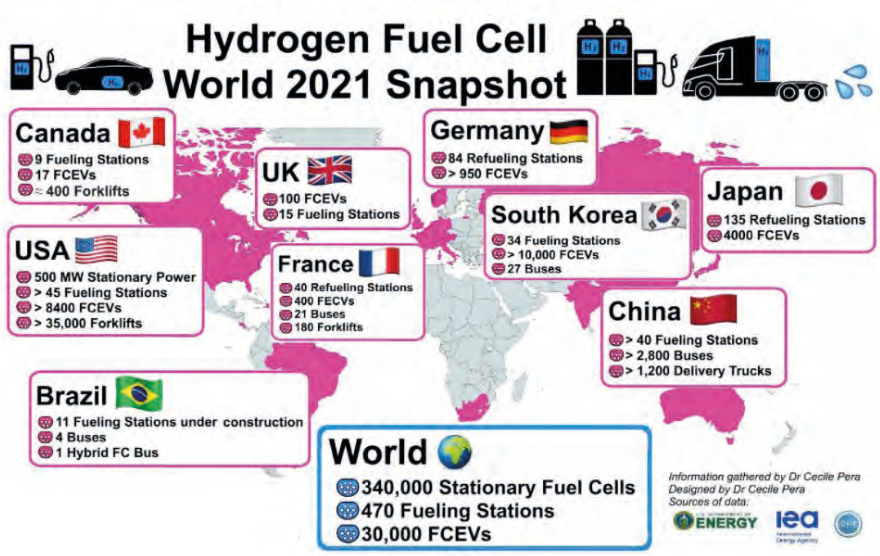
More than a dozen alternative fuels are in production or under development for use in alternative fuel vehicles and advanced technology vehicles. Government and private-sector vehicle fleets are the primary users for most of these fuels and vehicles, but individual consumers are increasingly interested in them. Using alternative fuels and advanced vehicles instead of conventional fuels and vehicles helps the United States conserve fuel and lower vehicle emissions.

Figure 3: Several Fuels of FCEVs
Source: afdc.energy.gov

The increased number of retail hydrogen fueling locations in select markets is supporting the initial rollout of fuel cell electric vehicles (FCEVs). Manufacturers including Honda, Hyundai, and Toyota are currently offering production FCEVs for sale or lease to customers in markets.

Mobile hydrogen fuelers, where liquefied or compressed hydrogen and dispensing equipment is stored onboard a trailer, are also should be developed to support the expansion of hydrogen infrastructure.

Figure 4: Hydrogen Fuell Cell 2021 World Overview
Source: compilation from multiple sources (DoE, IEA, IPHE, Orovel.net)



Policy of FCVs and hydrogen stations of some countries

A hydrogen infrastructure is the infrastructure of hydrogen pipeline transport, hydrogen production points, and hydrogen stations (sometimes clustered as a hydrogen highway) for the distribution and sale of hydrogen fuel, and is thus a critical prerequisite for the successful commercialization of automotive fuel cell technology.

A. US POLICY

- **Airport Zero Emission Vehicle (ZEV) and Infrastructure Incentives**
  The Zero Emissions Airport Vehicle and Infrastructure Pilot Program provides funding to airports for up to 50% of the cost to acquire ZEVs and install or modify supporting infrastructure for acquired vehicles.

- **Alternative Fuel Corridor (AFC) Grants**
  The U.S. Department of Transportation (DOT) must establish a competitive grant program to strategically deploy publicly accessible electric vehicle charging and hydrogen, propane, and natural gas fueling infrastructure along designated DOT Federal Highway Administration AFCs.

- **Alternative Fuel Excise Tax Credit**
  A tax incentive is available for alternative fuel that is sold for use or used as a fuel to operate a motor vehicle. A tax credit in the amount oof $0.50 per gallon is available for the following alternative fuels: natural gas, liquefied hydrogen, propane, P-Series fuel, liquid fuel derived from coal through the Fischer-Tropsch process, and compressed or liquefied gas derived from biomass.

B. KOREA POLICY

After the announcement of the state-led plan titled "Hydrogen Economy Roadmap" in January 2019, the Korean government has sought a more active role in assisting hydrogen company growth. The government's effort to enact the world's first legislation on the hydrogen industry dubbed the "Hydrogen Economy Promotion and Safety Management Act" (Hydrogen Act), which recently entered into force on Feb. 5, 2021, was deemed to be the very first step toward a transition toward the hydrogen economy.

Table 1: Policy & Objective
Source: "Hydrogen Economy Roadmap" in January 2019

Policy	Objective
Hydrogen Economy Roadmap ('19.1.17)	1. Set a target to become a leading country in the hydrogen industry with two vital pillars: FCEVs and fuel cells 2. Provide all-encompassing policies that broadly extend to the overall hydrogen production cycle from fuel generation, storage, transport to utilization, goals and action plans to push forward the hydrogen agenda by 2040 which aims to make "hydrogen economy" a new growth driver and source for the global transition towards clean energy
Hydrogen Economic Standardization Strategy Roadmap ('19.4.3)	1. Set international industry standards particularly in the areas where Korea can take the lead in related technologies (to acquire 20% of the industry standard certificates) 2. Enforce national industry standards in accordance with international technical standards in common use 3. Mandate technologies of key components to be accredited by the Korean
Plan to Develop Hydrogen Infrastructure and Refueling Station ('19.10.22)	1. (Supply of hydrogen energy) Meet hydrogen demand through production diversification and infrastructure development in storage and transportation 2. Continue efforts to ensure price stability and affordability of hydrogen power 3. (Installation of hydrogen refueling station) Establish 310 publicly available fueling stations in operation by 2022 4. General purpose + bus only services in major cities: 260 5. Nationwide transport hub including highways, rapid transit stations, etc.: 60
Hydrogen Technology Development Roadmap ('19.10.31)	1. (Hydrogen production) To meet energy demand, equivalent in volume to 5.26 mln tons by 2040 and to lower the energy price to KRW 3,000 per each kilogram, cheap enough to compete with fossil-fuel sources by 2040 2. Progressively develop green technologies to mitigate climate change and greenhouse gas emissions 3. (Safety/ Environment/ Infrastructure) Complete the entire process of facilitating industry base by the year 2030 as a means to pave the way for the development of hydrogen technologies applicable to the overall production cycle 4. (Hydrogen fueling infrastructure) Help improve manufacturing self-sufficiency, decreasing reliance on imported fueling technologies
Comprehensive Hydrogen Safety Management Plan ('19.12.26)	1. Facilitate safety management system to reach globally acceptable level (Enactment of Hydrogen Act, TF formation etc.) 2. Put primary focus on facility management (three main facilities: fueling stations, hydrogen production hubs, fuel cell power plants 3. Embrace sustainable, safe hydrogen economy/Promote a culture of health and
Hydrogen Act ('20.1.9)	1. Passed the world's first "Hydrogen Economy Promotion and Safety Management Act" at the 2020 legislative session 2. Put legislative ground in place in relation to safe use of low-pressure electrolysers (using renewable energy sources to supply hydrogen power) and
Plan to Improve Competitiveness in the Hydrogen Ecosystem ('20.7.1)	production, transport and utilization of the hydrogen economy 2) Devise policies to encourage more companies to join activities in the hydrogen sector 2. (Local municipalities) 1) Lay out a plan to ensure stable supply of hydrogen energy 2) Build multilateral partnerships to network among the government, municipalities and locally based innovative businesses and to form a hydrogen ecosystem 3. (Global business) Run business projects overseas* to help the hydrogen ecosystem in Korea scale up and take the lead in the global hydrogen industry

C. CANADA POLICY

There are various reasons why hydrogen fuel cell vehicles could be beneficial, especially to Canada's economy, and contribute to the country's transition to a more sustainable on-road transportation future. For starters, Canada has a large number of hydrogen and fuel cell enterprises that cover every aspect of the transportation supply chain, including hydrogen production and delivery, refueling stations, and fuel cell car engineering and manufacturing.

Table 2: Fueling Infrastructure in Canada
Source: Canadian Hydrogen and Association

Area	Company	Headquarters
Hydrogen production	Air Products Canada	Edmonton, AB
	Advanced Flow Systems	Maple Ridge, BC
	Enbridge Gas Distribution	Calgary, AB
	Hydrogenics	Mississauga, ON
	Luxfer Canada Ltd.	Calgary, AB
	Next Hydrogen	Mississauga, ON
	Nu:ionic Technologies	Fredericton, NB
	Quadrogen Power Systems	Burnaby, BC
	Xebec Adsorption Inc.	Blainville, QC
Hydrogen refueling infrastructure	Associated Plastics and Supply Corp.	Vancouver, BC
	Aurora Scientific Corp.	Aurora, ON
	Change Energy Services Inc.	Oakville, ON
	Hydrogen Technology and Energy Corporation	Vancouver, BC
	Hydra Energy Corp.	Delta, BC
	Hydrogen In Motion Inc.	Vancouver, BC
	IRDI System	Richmond, BC
	Kraus Global Ltd. Dispensing Solutions	Winnipeg, MB
	Powertech Labs Inc.	Surrey, BC
Hydrogen fuel cell manufacturing	Ballard Power Systems	Burnaby, BC
	Dana Canada	Oakville, ON
	Loop Energy	Burnaby, BC
	Overdrive Fuel Cell Engineering Inc.	Burnaby, BC
	Palcan Energy Corp.	Vancouver, BC
	Zen Clean Energy Solutions Inc.	Vancouver, BC

Table 2 summarizes the activities of a number of Canadian companies in these three sectors. British Columbia has the largest cluster of hydrogen and fuel cell companies in Canada, but there are other companies in Ontario, Alberta, New Brunswick, and Manitoba.

FCEVS SEMINARS SUPPLY OF HYDROGEN STATIONS

In 2021, Task 35 seminars were held.
The first Task 35 was held at University of Ulsan, Ulsan, Republic of Korea on 25th November 2021. The Topics presented and discussed at the seminar were:

- Global Hydrogen Road Map
- Hydrogen Mobility
- Fuel Cell Applications
- Hydrogen Industry Value Chain

INTERNATIONAL CONFERENCE FOR NEXT GENERATION MOBILITY USING FUEL CELL

TECHNOLOGY

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TASK 37

Extreme Fast Charging

MEMBER COUNTRIES
UNITED STATES

INTRODUCTION

Battery electric vehicles (BEVs) have continued to increase their market share worldwide, with advantages in efficiency, low operating costs, and emissions. However, despite decreases in cost within the BEV powertrain and significant improvements in drivability and performance, the BEV market still accounts for a small share of new vehicle sales annually. An identified gap to wider adoption of BEVs is the ability to refuel quickly or to fast charge. Currently, the majority of BEV recharging is done at home, but data shows that having access to public direct current (DC) fast chargers can have a big impact on BEV utility from a consumer perspective. Studies have shown that in areas where drivers have access to 50-kW or 120-kW fast charge stations, annual electric vehicle (EV) miles traveled increased by over 25%, even in cases where fast charging was used for 1% to 5% of total charging events [1,2]. Having access to these fast charge stations can help alleviate the “range anxiety” commonly cited as a reason for consumer hesitation to buy a BEV.

Based on these trends, even higher power charging stations could drive further BEV adoption. To address the fast charge barrier, charging at power levels up to and even exceeding 400 kW, often referred to as extreme fast charging (XFC), have been proposed. This task focuses on XFC technology, gaps, installations, and operations.

OBJECTIVES

Task 37 is focusing on the following objectives: investigating station siting – what factors are considered (i.e. space requirements, city center, community/corridor, etc.); quantifying the costs of installation – including physical site location and infrastructure costs, as well as costs associated with the charging equipment; documenting grid connection details for current and planned installations, including any co-located renewable generation or energy storage; understanding the implications of XFC on battery design, performance, and cost; documenting pay structures and/or consumer interfaces for payment; and studying consumer education methods and topics.

WORKING METHOD

Task 37 continues to finalize member countries and is currently reporting out XFC related activities and reports from the United States. The task plans to organize a series of workshops scheduled in conjunction with dedicated conferences and IA-HEV Executive Committee (ExCo) meetings. The workshops will gather a variety of stakeholders coming from academia, industry, and public authorities. Workshops may also include site visits to XFC installations, providers, or manufacturers. The purpose is to identify trends and scenarios, to analyze challenges and opportunities, and to deliver conclusions for future actions.

RESULTS

Charging infrastructure for vehicle charging at 400 kW and beyond from a multi-port refueling plaza similar to today's gasoline stations will reasonably require at least 1 MW of power conversion capability. A load of this magnitude is expected to require a primary voltage service from the electrical distribution infrastructure. While this could be served by onsite low-frequency transformers, this has been identified as an opportunity to investigate direct medium voltage (MV) grid-tied connected power electronics to improve efficiencies, as well as reduce installation footprints. The following sections provide a summary of US Department of Energy (DOE) industry-led efforts, which are developing designs for light-duty vehicle charging stations to deliver at least 1 MW of combined load or connect directly to medium voltage grid feeds.

System Architectures

Vehicle charging at power levels from 350 to 400 kW per vehicle at a refueling plaza with 4 to 12 charging ports would lead to a site design with a power conversion and grid capacity of between 1.5 and 5.1 MW. This calculation implies that the power conversion at all ports would occur at peak power at the same time; however, this might only be between 33% and 47% of the peak rating based on the charging profile and coincidence arrival times of the vehicles[3]. Consideration of the coincident peak power from all charging ports and a desire to include integration with local distributed energy resources (DER), such as photovoltaics or stationary electrochemical energy storage, leads to a design in which the required input power conversion from the grid can be lower than the sum of the charging ports. A similar power conversion architecture has resulted from these constraints in the DOE industry-led efforts, as shown in Figure 1. This architecture includes an input solid-state transformer (SST) conversion from medium voltage ac at the grid to a common dc bus in which dc-dc converters for each vehicle charging port and the DER are connected.

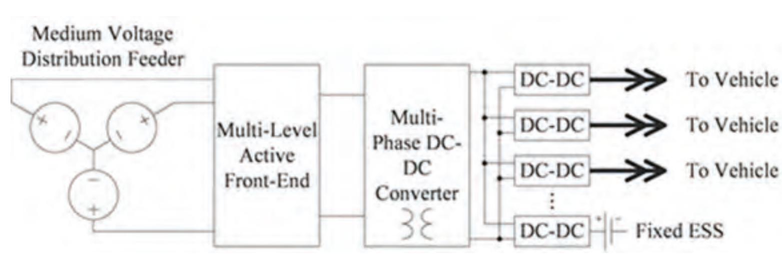

Figure 1: Block diagram schematic of an XFC refueling plaza

Source: See reference 4

The SST portion of the system is the medium voltage input from the grid to the common DC bus, which consists of two conversion stages in these systems. The stages: (1) ac-dc conversion in the active front end, and (2) an isolated dual active bridge dc-dc conversion utilizing a high frequency transformer for galvanic isolation. The active front end stage is configured in an input-series output-parallel approach to allow for the input ac grid voltage to be divided into a smaller voltage and lower power rating for conversion to a common output. This topology allows for a modular approach in which the conversion hardware can be configured for all possible medium voltage inputs from 4.16 kV up to 13.8 kV at scalable power conversion levels based on the site (or port count) requirements. The following table provides a comparison of the topology, switching devices, and voltage of each stage of the SSTs in the DOE industry-led efforts.

Table 1: Solid-State Transformer Designs for Extreme Fast Charging R&D Projects

Project	AC/DC (AFE)	DC/DC Primary	DC/DC Secondary
High-Efficiency, MV-Input, Solid-State-Transformer-Based 400-kW/1000V/400A Extreme Fast Charger for Electric Vehicles	Multilevel Cascaded H-Bridge (CHB)	CLLC Full Bridge	Full Bridge
	1.2 kV SiC MOSFET	1.2 kV SiC MOSFET	1.7 kV SiC MOSFET
	Input: 13.2 kVAC	1.6 kVDC	Output: 1.1 kVDC
Intelligent, Grid-Friendly, Modular Extreme Fast Charging System with Solid-State DC Protection	Multilevel Cascaded H-Bridge (CHB)	Neutral Point Clamped (NPC) Full Bridge	Full Bridge
	1.2 kV SiC MOSFET	1.7 kV SiC MOSFET	1.2 kV SiC MOSFET
	13.2 kVAC	2.1 kVDC	Output: 0.75 kVDC
DC Conversion Equipment Connected to the Medium-Voltage Grid for XFC Utilizing Modular and Interoperable Architecture	Full Bridge	Full Bridge	Full Bridge
	1.7 kV SiC MOSFET	-	-
	Input: 13.2 kVAC	1.2 kVDC	Output: 0.95 kVDC
Enabling Extreme Fast Charging with Energy Storage	Multilevel Cascaded H-Bridge (CHB)	Full Bridge	Full Bridge
	1.2 kV IGBT	-	-

System Performance

The medium voltage connected power electronics explored in these efforts is a new approach to XFC systems, which would traditionally be served by an onsite low-frequency transformer stepping the voltage down to 480 VAC. The primary benefits of this approach include the removal of the bulky transformer and reductions in the associated AC wiring, as the higher voltage allows for smaller conductor sizes. This high-frequency approach has been investigated and shows promise in reducing the volume, mass, efficiency, and equipment footprint, as seen in Figure 2. The conventional system in the figure is composed from left to right with a transformer, AC switchboard, and the charging hardware. The proposed system is composed from left to right with a medium voltage fuse metering enclosure, switch gear, and the charging hardware.

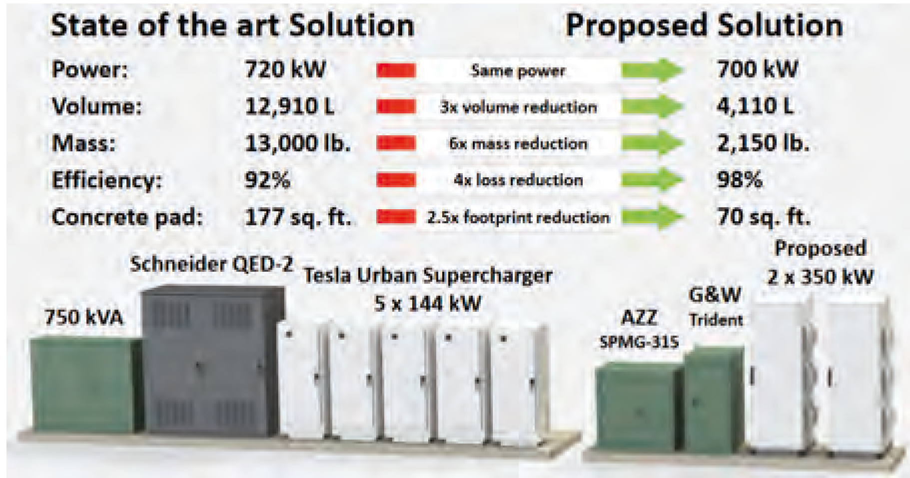

Figure 2: Benefits of Medium Voltage Extreme Fast Charging

Source: See reference 5

The High-Efficiency, MV-Input, Solid-State-Transformer-Based 400-kW/ 1000V/ 400A Extreme Fast Charger for Electric Vehicles project conducted a demonstration of their completed system on September 28, 2020, see Figure 4. This system contains the 13.2 kV medium voltage SST, which is rated for 400 kW. The dimensions of the system are 3100x 1300x 2100 mm with an approximate mass of 3000 kg. The charger power cabinet is similarly rated at 400 kW, with dimensions of 600x 400x 2400 mm and a mass of 800 kg. The combined system volume is 9039 L, the footprint is 4.27 m2 (46 sq. ft.), and the mass is 3800 kg (8379 lb.). Compared to the conventional solution shown in Figure 2, this represents about a 2x reduction in footprint and increase an increase of about 1.26x in volume and 1.16x in mass relative to the output power rating.

Figure 4: 400kW XFC (SST, Charger Power Cabinet, Dispenser, and DCE from left to right

Source: See reference 12

The peak system efficiency of the 400kW XFC system shown in Figure 4 is over 96.5% for DC output voltages about 800V from 25% to 100% of full power, with a peak efficiency of 97.6% and total power factor of 0.995. For the SST by itself, this stage has a peak efficiency for medium voltage ac conversion to dc of 98.5%.

Similarly, the Intelligent, Grid-Friendly, Modular Extreme Fast Charging System with Solid-State Direct-Current Protection project has found for its prototype SST at full power of an efficiency of 98.9%. The project has recently optimized the 13.2 kV 1-MW SST system to achieve a total volume of 3000 L with an approximate mass of 2000 kg. Figure 5 below shows a completed single module utilized in the SST. These projects show that a medium voltage connected system when compared to a conventional system can achieve 2x improvement in system losses, with a significant reduction in total installation footprint and weight.

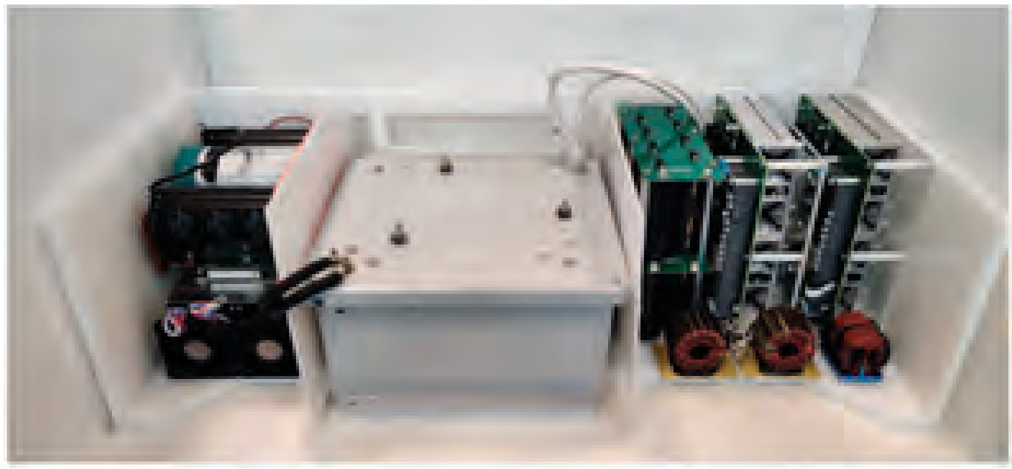

Figure 5: Single Module Utilized in 1-MW SST Rack

Source: See reference 13

NEXT STEPS

Thus far, Task 37 has identified the following key challenges for the task to investigate critical barriers to the widespread deployment of extreme fast charging:

- Medium-voltage power conversion equipment – Design of charging equipment that directly connects to the MV distribution may improve operating costs through more efficient power conversion and reduce capital costs by reducing the footprint of the installed equipment on the site.
- Integrated charging sites – Charging sites that incorporate onsite generation and storage technologies may benefit from reduced electricity costs by shifting load. Development of these sites in conjunction with existing large load facilities may prove beneficial if controllable load, generation, and storage resources can be leveraged across the site.
- Grid interaction and interconnection- Connection of highly dynamic large (>1 MW) non-linear load will require utility assessment and may require costly infrastructure improvements to ensure stable operation of the distribution system. A foundational understanding of the grid integration of extreme fast chargers is needed to develop a harmonized interaction of the charging hardware and support rapid growth of extreme fast charging sites.

The task is working to gain participation from other countries to further investigate and refine these objectives. Future meetings and workshops will be scheduled with input from members.

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TASK 38

Marine Applications (E-Ships)

MEMBER COUNTRIES
CANADA
CHILE
DENMARK
NORWAY

INTRODUCTION

Task 38 was initially approved by the HEV TPC in 2017 and activities were preliminarily started in 2018/2019. However, the Task was later placed on hold due to a change of Operating Agent and the outbreak of the Covid-19 pandemic. National Norwegian funding for supporting the role of Operating Agent was confirmed in 2021 and the Task was formally restarted in November 2021, with plans for three years of operation.

Denmark first proposed the Task, with confirmed participation from Canada, The Netherlands and Norway and ongoing discussions with several other interested countries. At the first attempt of starting the Task, Chile had also confirmed interest in participating as a limited sponsor. By the end of 2021, actively participating members were only confirmed from Norway and Chile, while commitment of Task members was pending from Canada, Denmark, The Netherlands, and the USA. Discussions with other interested parties are also ongoing, and new members are encouraged to join the Task as further activities will be started during 2022. The scope, deliverables and meeting schedule of the Task will be refined and consolidated during 2022 in cooperation with the participants that will be confirmed during the year.

The technical focus of Task 38 is on fully battery-electric ships and related issues, such as battery technology and shore-to-ship charging systems. However, the Task will also cover technology for hybrid battery-electric propulsion systems, including retrofit of battery storage into existing vessels for reducing emissions. The primary activities in the Task will be to gather and share key knowledge on projects, technology performance, segments, and demand to support wider applications of the rapidly developing technology for electrification of vessels for reducing emissions from marine transport.

OBJECTIVES

The main objective of Task 38 is to survey and encourage research, development, and deployment of marine vessels with onboard battery storage systems. Thus, the Task will focus on gathering and sharing key knowledge on existing and planned projects for demonstration or deployment of battery-electric vessels, identification of achievable performance for key technologies, and the feasibility of electrification in different application segments. Depending on the interest of participants in the Task, activities can also cover identification of demand and market potential in key vessel segments suitable for electrification.

The main objective will be achieved by pursuing the following activities:

- Providing an international network and general platform for sharing information among researchers, industry and policymakers involved in electrification of marine transport as a means for reducing national and global emissions.
- Cooperation with other international activities for bridging 'blue' maritime applications, 'green' energy technology, and e-mobility development, including energy system integration, charging technology and automation perspectives.
- Survey, characterize, and showcase emerging technology, economics, policies, energy, and environmental aspects, applications and market potentials associated with electrification of marine transport.
- Document and disseminate results from pioneering projects and experiences from success cases based on utilization of batteries in marine applications
- Analyze and document the current drivers and future perspectives for battery applications in marine vessels.
- Look for segmentation, convergence and scaling of supply and demand.
- Provide knowledge and data that can be used as basis for policy development and other initiatives for advancing the technology, commercial adoption, and market acceptance of battery-electric ships.

WORKING METHOD

The first activity in the Task is the organization of a series of webinars and online meetings for spreading information about cutting edge technology, pioneering deployment projects, and experiences from successful operation of electrified vessels. These webinars are being organized in the period from the end of 2021 and until the summer 2022. They are intended to disseminate information from research and industrial development, while attracting additional countries and stakeholders to join the Task.

After the initial webinar series, the Task will be based on the organization of bi-annual meetings or workshops, under the assumption that the development of the Covid-19 pandemic will allow for international travel after the summer 2022. Each meeting will be focused on a specific subtopic within the scope of the Task. The events will be planned in different member countries and regions, and will involve stakeholders from various research institutes, maritime organizations, battery technology companies, system integrators, shipbuilders, and shipowners, etc. Furthermore, the meeting locations will be selected to allow for visiting relevant demonstration projects or technology providers, ensuring that the international group of participants can gain first-hand experience with the operation of emerging technology. When relevant, the meetings will also be coordinated with national or international conferences or seminars on related topics, allowing the participants to maximize the benefits from travelling. It is expected that the first meetings of the Task will be focused on developments in Europe, while some of the subsequent meetings or workshops will be organized in Asia and in the Americas, with a focus on local developments and application areas. Some of the meetings will also be coordinated with activities in Task 47 "Electrification of ground freight related to port electrification".

During the operation of the Task, all members will collect data about technology, projects, policies, economics, environmental aspects, etc. from their countries and internationally according to their specialized competences and corresponding networks. The gathered information and data on the available and emerging technology and on future application prospects will be discussed and documented within the Task. Thus, members will get the opportunity to learn about emerging technologies, standardization efforts, key stakeholders, best practices, environmental impact, and industrial perspective, including corresponding policies and measures aimed at successful commercialization of technology for electrification of marine transport. Development of regional and national initiatives for reducing emissions from marine transport can be facilitated by the access to a wide international network of interested industry, researchers and public entities expected to become available within the Task.

RESULTS

The first result after restarting activities in Task 38 was a webinar on "Experiences and Outlook on Technology for Electrification of vessels" organized on the 15th of December 2021. The webinar featured the following technical presentations, followed by questions and discussions:

1. "Zero emission battery ferries – from vision to reality," by Atle Rygg, Siemens Energy, Norway

2. "Development of hybrid marine vessels in Chile" by Joel Pérez Osses, Universidad Austral de Chile,

3. "Development of battery-electric high speed passenger vessels" by Edmund Tolo, Fjellstrand Yard, Norway

The first presentation covered the developments of technology for fully battery-electric propulsion of ferries in Norway, and considerations on the status with respect to feasible capacity and range for such vessels from the perspective of Siemens Energy. The presentation highlighted how Norway, after M/F Ampere started operation as the world's first fully battery-electric car ferry in 2015, has already confirmed operation of more than 60 ferries with battery-electric or plug-in hybrid operation depending on charging from the onshore power system. Furthermore, the number of electrified ferries is expected to exceed 100 within 2024. Typical power system configurations and design constraints of the battery system were also presented, based on an example of a ferry with 3.4 MWh battery capacity which has been recently commissioned in Norway.

The second presentation introduced the status and plans for research and industrial development of battery-hybrid vessels in Chile. The presentation included an overview of the main types of vessels in the current Chilean fleet, to indicate the potential for electrification of the most relevant vessel segments. Furthermore, the presentation included discussions on the challenges of energy efficiency evaluation of vessels, and a brief introduction to an ongoing project for development and application of hybrid aquaculture support vessels in Chile.

The third presentation discussed the design of zero emission vessels from the perspective of ship design and shipbuilding. After introducing background information on previous initiatives for assessing battery-based operation of ferries, the presentation covered the experiences from the design of the M/F Ampere as the first fully battery-electric ferry. On this basis, the presentation outlined how the further development of technology has enabled longer routes to be operated only on batteries, and how the experiences from ferries are now being utilized for designing a high-speed passenger vessel. An ongoing development project was also presented, showcasing a high-speed vessel with capacity for 147 passengers, which is designed for operation up to 23 knots. The construction of the vessel was started during 2021, and it is expected to be finalized and ready for starting operation in Stavanger, Norway, during 2022.

NEXT STEPS

The next steps for the Task will be the organization of three webinars during the first half of 2022. The first step will be a webinar on high power charging technology for battery-electric and plug-in hybrid vessels, which is being planned for the end of March 2022. The following step will be a webinar dedicated to battery technology for marine application, and the last of the planned webinars will be addressing the outlook for electrification of different vessel segments with their associated challenges and potential for emission reduction.

In parallel to the organization of the webinar series, the Task is looking for new members and for confirmation of participants from countries having already expressed interest in the Task. Participating countries and organizations are expected to join efforts in terms of organization of the future meetings and workshops for collecting, exchanging, and disseminating information and experience on aspects within the scope of the Task.

The next major step will be to organize the first regular meeting of the Task in the middle of 2022. After confirming the active participants in the Task, the first phase of meetings and discussions will focus on technology, projects, policies and potential deployment in Scandinavia and Europe, where a high number of battery-electric vessels are already in operation. The second phase will include the Americas, and the third phase will overview Asia and the rest of the world. A more detailed plan for the meetings will be agreed when the participants in the Task from at least five member countries are confirmed. Additional online meetings will also be agreed according to need during 2022 while consolidating the participation and the further plans for activities in the Task. This will also include coordination with other Tasks, including Task 47 on "Electrification of ground freight related to port electrification".

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TASK 39

Interoperability of e-mobility services

MEMBER COUNTRIES
BELGIUM
CANADA
FRANCE
SPAIN
SWITZERLAND
THE NETHERLANDS
UNITED STATES

INTRODUCTION

The IEA TCP HEV Executive Committee (ExCo) unanimously approved Task39 at the 48th ExCo meeting held in April 2018 in Dublin (Ireland). At the 52nd ExCo meeting held in November 2020 as an online meeting, an extension has been requested due to the impact of COVID-19 on the Task39 planning. The extension has been approved and Task39 is now running from 01/04/2018 until 30/03/2022.

Belgium initiated Task 39 and The Netherlands officially joined from the start. During the first year, many countries expressed an interest to join Task39: Switzerland, United States, Spain, Canada, Germany, UK, Sweden, and France. Most of these countries have joined officially. Also, with the European Commission contacts are ongoing to share experiences related to their interoperability activities within the "European Interoperability Centre for Electric Vehicles and Smart Grids" and related to the AFID directive on the deployment of alternative fuels infrastructure in Europe.

Task39 will focus on user friendly charging infrastructure, more specifically at the interoperability aspects for charging passenger cars in the public and semi-public domain. Also, Smart charging is within the scope of Task39.

The market of electric vehicles is growing worldwide at an increasing speed. More and more electric vehicle models are being introduced on the market. End users and governments get more and more interested in the potential benefits of electric mobility since it offers a great potential to solve many of our environmental, societal and economic challenges. Therefore, policy makers are implementing supportive measures to facilitate the further uptake of electric mobility in their region. The main barriers to be addressed are the higher purchase cost, limited driving range and limited charging infrastructure.

The European Green Deal, published by the European Commission in December 2019, states that by 2025 about 1 million public recharging points will be needed for the 13 million zero- and low-emission vehicles expected on the roads of the European Union (EU). Governments and industry are making huge investments in charging infrastructure in the public and semi-public domain to facilitate the further uptake of electric mobility. Charging infrastructure will be needed, in more or less quantities, at all locations: residential, workplace and the semi-public and public domain.

By the end of 2020, there were about 2 million passenger cars (BEVs and PHEVs) in the 27 EU Member States and this number increased to more than 3.8 million at the end of 2021. By the end of 2021, there were about 260,000 publicly accessible recharging points across the EU-27 Member States, of which 85% were normal power recharging points (up to 22 kilowatts), and 15% high power recharging points (above 22 kilowatts). The top 5 countries with the highest numbers of publicly accessible recharging points are: The Netherlands, Germany, France, Italy, and Sweden (source: EAFO - EAFO - European Alternative Fuels Observatory).

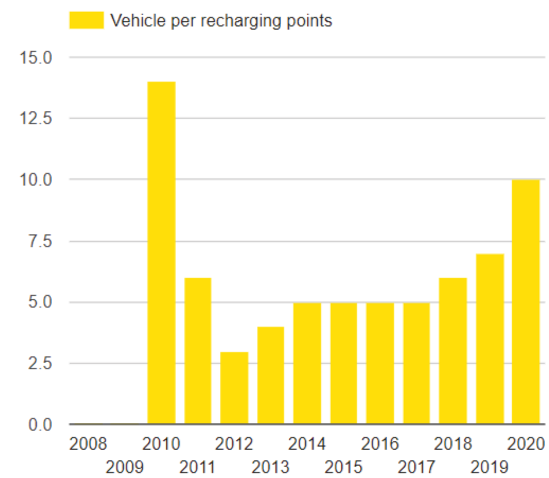

Figure 1: Number of Plug-in Electric Vehicles (PEV) per public recharging point in European Union (Source: EAFO - European Alternative Fuels Observatory)

However, it is not only about the quantity of available charging points in a region. Different studies refer to an indicative ratio that is needed of at least 1 charging point per 10-12 electric vehicles, but this ratio is of course very dependent on the local situation. On European Union level, we see, however, that this ratio went from 10 in 2020 up to 15 in 2021 (see Figure 1).

Equally important to this ratio/quantity, is the quality of the charging service offered to the end users. This charging service needs to be easy to use, reliable and cost transparent. Information about the location and availability of charging points, about the way to get access to these charging points, about the tariffs, are crucial for the end user to be confident enough to make the step the electric mobility. Interoperability between the different e-mobility services offered today is therefore crucial for the comfort and ease-of-use of the end users. Look at the roaming in the telecom sector. But interoperability is equally important for the governments and companies making investments in charging infrastructure and services. Information exchange between the back offices of the different stakeholders like charge point operators and mobility service providers is an important aspect and having open and interoperable solutions can have a positive impact on the business case and on the flexibility to offer higher quality and/or combined e-mobility services to the end user.

OBJECTIVES

Today, most EV drivers are still lacking easy access to all necessary information about the charging possibilities in their region. Interoperability between countries is even a bigger problem. Many initiatives are being taken to improve information and interoperability, but today EV drivers still have to put too much time and effort into collecting this crucial information about the charging infrastructure (location, availability, accessibility, pricing) for their specific charging needs. Only the EV addicts will do this effort and most other people interested in electric mobility will wait until this situation improves. Steps for improvement are being made, but not all issues have been solved completely like e.g. having a clear upfront view on the costs of charging at all locations.

Task39 will bring together experts from member countries to share information and best practices to improve the interoperability and accessibility of charging services:

- An overview of the ongoing initiatives to stimulate interoperability of e-mobility services will be set-up.
- Every member country will also write a detailed country report, explaining the current local market organization (market players & supporting policy measures), which will be very valuable information for the EV drivers in that specific country.
- Ultimately, Task39 will set up recommendations for governments and industry how to improve the interoperability of charging services. The main focus in Task39 will be on "standard" charging services, but also the aspect of "smart" charging and its interoperability aspects will be taken into account.

On European Union level, progress is being made via the Commission's proposal to revise the Alternative Fuels Infrastructure Directive (AFID) and to transform it into a regulation setting binding targets for charging infrastructure rollout at member state level.

WORKING METHOD

Task39 will be executed in a pragmatic way and will make use of mainly telco's and workshops to collect, discuss and write down the existing knowledge available at the experts from the member countries. This information will be complemented by additional desktop research and contacts with different initiatives to collect the most recent information. All collected information will be stored in the IEA TCP HEV SharePoint site and will be accessible to the member countries. Putting the available information on paper concisely and sharing it with the EV community (end users, governments, and industry) is the ultimate ambition of Task39. The country reports and recommendations will be shared via the Annual Report and the website of IEA TCP HEV.

RESULTS

Task39 started with the collection of relevant information **via desktop research and contacts with experts in the field.** Many projects dealing with interoperability and roaming have been studied.

The information collected via desktop research, workshops and direct contacts is stored in a dedicated **Task39 SharePoint site** hosted at VITO and which is accessible for all Task39 member countries. With the same login, the member countries also get access to the knowledge database of the Flemish Knowledge Platform Smart Charging with literature on smart charging.

Focus at the start of the desktop research was mainly on Europe, because a lot of the ongoing projects detected have been set-up with European funding (FP7, H2020 or Interreg). Thanks to member countries Canada and the United States, information from outside of Europe is also available.

The funded projects selected in the desktop research, study the interoperability aspects from different perspectives. Examples of **European funded projects** studied in the first period of Task39 were Interreg-evRoaming4EU (https://www.evroaming4.eu), PF7–Cotevos (http://cotevos.eu) and H2020-NeMo (http://nemo-emobility.eu/).

More recently, the **H2020 call on "User centric charging infrastructure"** (LC-GV-03-2019) was launched which focused on many Task39 related topics. Three projects have been funded within this call:

- **eCharge4Drivers:** Electric Vehicle Charging Infrastructure for improved User Experience (https://echarge4drivers.eu/)
- **INCIT-EV:** Large demonstratIoN of user CentrIc urban and long-range charging solutions to boosT an engaging deployment of Electric Vehicles in Europe (https://www.incit-ev.eu/)
- **USER-CHI:** Innovative solutions for USER centric CHarging Infrastructure (https://www.userchi.eu/)

Besides funded projects, we also see market players joining forces in initiatives like **eMI3 "eMobility ICT Interoperability Innovation Group"** (www.emi3group.com). Under the umbrella of ERTICO, the eMI³ Group is an open interest group of global market players to enable global EV services interoperability by harmonizing existing and preparing standardization of future ICT data standards & protocols including security and authentication. Examples of members of eMI3 are roaming platforms like Hubject (www.hubject.com) and Gireve (www.gireve.com) and also Task39 partner ElaadNL (https://www.elaad.nl/) is a member of eMI3.

Task39 is following closely the activities around the **AFID Directive 2014/94/EU on the deployment of alternative fuels infrastructure in Europe.** The European Commission launched a proposal to revise the Alternative Fuels Infrastructure Directive (AFID) and to transform it into a regulation setting binding targets for charging infrastructure rollout at member state level (**Alternative Fuels Infrastructure Regulation, AFIR**). The conversion into a regulation will ensure swift and direct implementation, supporting a coherent and interoperable network for private and professional users in line with the electric vehicle market's growth. Fleet-based targets will ensure infrastructure growth goes hand in hand with EV uptake, resolving the "chicken-and-egg" problem, whereas distance-based targets along the TEN-T network will put an end to range anxiety for drivers across the continent.

The Sustainable Transport Forum (STF) was set up to assist the European Commission and serves as a platform for structural dialogue, exchange of technical knowledge, cooperation and coordination between Union Member States and relevant public and private stakeholders. Its mandate has just been extended until 31 December 2030. DG MOVE may set up sub-groups, that report to the STF plenary, for the purpose of examining specific questions on the basis of terms of reference defined by DG MOVE. The following **Sustainable Transport Forum sub-groups** are currently active or in the process of being set up:

- **Sub-group on the implementation of Directive 2014/94/EU:** this sub-group consists of the Member States only and discusses specific aspects related to the implementation of the Alternative Fuels Infrastructure Directive 2014/94/EU.

- **Sub-group on governance and standards for communication exchange in the electromobility ecosystem (with a particular focus on ISO 15118-20 and related PKI):** this sub-group will propose minimum principles and a governance framework for communication between the electric vehicle and the recharging infrastructure, ensuring interoperability in the whole ecosystem. It will moreover prepare the ground for harmonisation and convergence of electromobility communication standards and protocols.

- **Sub-group on a common data approach for electric mobility and other alternative fuels:** building on the work of the Program Support Action (PSA) on data collection related to recharging/refueling points for alternative fuels and the unique identification codes related to e-Mobility (IDACS), this sub-group will look into the different data dimensions (aggregation, quality, sharing, reusability, provision, etc.) and data types (location, availability, price, payment methods, etc.) required to enable the future creation of new digital services in the alternative fuels market. It will propose a framework for data collection and exchange, with the ultimate objective to provide better information to consumers of alternative fuels infrastructure and services.

- **Sub-group on best practices of public authorities to support the deployment of recharging infrastructure:** this sub-group, which consists of public authorities mainly, will further the work on the 2020 STF Recommendations for public authorities for procuring, awarding concessions, licenses, and/or granting support for electric recharging infrastructure, generating a (bi-)annual update to ensure the Recommendations remain relevant for public authorities. The sub-group will moreover look into possibilities to harmonise permitting procedures for alternative fuels infrastructure in the EU.

Within the **Task39 member countries**, one of the first countries taking interoperability serious on a national and cross-border level is The Netherlands. The Dutch developed a national agenda for charging infrastructure (https://english.rvo.nl/information/electric-transport) and have been working many years towards an open and interoperable charging infrastructure market. Task39 is very pleased that The Netherlands joined with 3 experts so that their experience can be shared with the other member countries: ElaadNL (www.elaad.nl), eViolin.nl (www.eViolin.nl) and NKL (www.nklnederland.com).

Interoperability is of course not only a national or European issue, it is also important that some aspects are being discussed on an **international level**. Thanks to member countries Canada and the United States, information from outside of Europe is also exchanged within Task39. The European Commission's Joint Research Centre (JRC) and U.S. Department of Energy's Argonne National Laboratory already work together via their **EV-Smart Grid Interoperability Centers**. They provide a venue for global industry-government cooperation that is focused on the joint development of EV standards and test procedures. The objective is to study interoperability issues between the electric vehicles and the charging infrastructure, covering hardware and information exchange protocols. Also, interoperability of the EV fleet and the smart grid is investigated. Pre-normative research is conducted to identify gaps in standards or technology and to support the formulation of regulations addressing interoperability issues.

Task39 workshops organized in 2021 have been focusing on important aspects like transparent pricing, EV market protocols and the importance of open protocols to stimulate interoperability, the role of the public and private stakeholders, data quality of available (semi-) public charging infrastructure and even on the growing importance of cyber security. The Task39 workshop on "Transparent Pricing and Invoicing" made clear that improvements need to be made on price transparency. Prices need to be clear to the EV drivers before, during and after the charging sessions. Today, there is still a large divergence and complexity in tariff structures for contract-based and ad-hoc charging.

NEXT STEPS

In 2022, Task39 will organize its **final workshop** and main efforts will be focused on finalizing the country chapters of the participating member countries and the Task39 final report.

The **country chapters** will be finalized by the respective member country and will describe the current local market organization (market players & supporting policy measures), which will be very valuable information for the EV drivers in that specific country. The country chapter of Canada has been finalized by BCIT in May 2020. All other country chapters will be disseminated via the next IEA TCP HEV Annual Report and website.

The **Task39 final report** will contain recommendations for governments and industry on how to improve the interoperability of charging services. This report will be written with support from all member countries and will be based on the information collected via desktop research, workshops, and experts contacts. In the Task39 final report we will refer to the latest information available and make links to best practices and guidelines.

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TASK 40

CRM4EV: Critical Raw Materials for Electric Vehicles

MEMBER COUNTRIES

IEA HEV MEMBERS

AUSTRIA
CHINA
FRANCE
GERMANY
THE NETHERLANDS
NORWAY
REPUBLIC OF KOREA
SPAIN
SWEDEN
UNITED STATES
UNITED KINGDOM

EXTERNAL MEMBERS

GOVT. OF WESTERN AUSTRALIA
AVERE
VALUAD

INTRODUCTION

Task force 40 "Critical Raw Materials for Electric Vehicles" of the IEA TCP "Hybrid and Electric Vehicle" (HEV) aims at providing accurate, credible and up-to-date information on materials which are considered as (potentially) critical for the uptake of electric vehicles sales.

Issues covered include: Which are the (potentially) critical raw materials for Electric Vehicles (EVs)? Which are the supply chain issues of these materials? What are other uses of these CRMs and how will they develop? Are there potential supply chain issues that will impact the future of mass deployment? If so, are these temporary or structural and under what circumstances would these issues occur? Are there alternative materials or solutions available, if so, are there any drawbacks? What are the impacts of evolving battery technologies? What is the nature of potential supply chain issues: material availability, environmental impacts, social impacts, geographical dependencies (concentration)?

Raw Materials under consideration included in the scope of Task 40 CRM4EV are those materials which are economically and strategically important for the mass deployment of EVs and have a high-risk associated with their supply. It is important to note that these materials can be classified as 'critical' for various reasons: 1) they have a high-supply risk due to limited mining (refining/smelting) capacity and/or a high level of concentration in particular countries, 2) there is a lack of (viable) substitutes, due to the very unique and relevant properties of these materials, as well as future applications for EVs, 3) there can be significant environmental impacts through the supply chain of these materials and intermediate products, 4) there can be significant issues concerning responsible sourcing of the materials and/or its intermediate products.

Materials like Lithium, Nickel, Cobalt, Graphite, Rare Earth Elements and others are already frequently in the news related to their (presumed) scarcity, environmental or social issues.

Conflicting information makes it difficult for policymakers to get fact-based and reliable information. This is especially the case for both ongoing and potential future discussions related to the future mass deployment of EVs. In fact, internal combustion engine technologies also require critical materials, which is often overlooked or already accepted in these debates. Fuel Cells currently use Platinum Group Metals (PGMs), as do catalysts for diesel cars.

Task 40 has been extended as of April 2021 for 1-1.5 years. The focus will be in this period to review impacts of the mass BEV deployment on the currently critical raw materials as well as the battery technology developments with respect to materials used with a trend to move away from potentially critical materials.

OBJECTIVES

The overall objective of Task 40 is to generate and continuously update the relevant information by and for Task 40 CRM4EV participants related to critical raw materials for EVs. This includes:

- Continuous data collection and (scenario) analyses including validation through various discussions within the workshops
- Developing global views as well as regional or country perspectives, based on the stakeholder needs (information, analysis, scenarios).

To achieve this, the Task has built a global representative network on the topic "Critical Materials for EVs" with stakeholders from administrations, industry, policymakers, researchers, and other relevant stakeholders representing the different value chains of the identified "in-scope" critical materials. External experts are involved as well. At HEV ExCo meeting in November 2020 it was decided to extend Task 40 by 1.5 years. For this extension period the number of stakeholders was reduced to avoid potential conflict-of-interest.

Figure 1: Task 40 CRM4EV participants and representative organizations delegated by IEA HEV participants (extension phase 2021-2022)

The network meets twice per year through workshops with several sub-groups for different critical materials/topics. The data needs and analyses from the participants will be used as the basis to define the detailed tasks to be conducted. The IEA HEV TCP participating countries will lead this work. As of 2020 due to the COVID pandemic no face-to-face workshops and meetings have been held, instead teleconferencing and webinar tools have been used.

WORKING METHOD

- Define and maintain a list of Critical Raw Materials to include in the scope of the Task CRM4EV.

- Define « criticality » of the Critical Raw Materials in scope:
    - Depending on geography
    - Depending on penetration rate in the EV application (scenarios)
    - Depending on the use of the CRM in EVs, cars and in other applications
    - Short term versus long term supply issues

- Evaluate (future) availability of alternative solutions or materials (e.g., Rare Earth Element free electro-motors, solid state batteries).

- Define the different sources (mines: where, what) and exploitable reserves of the different Critical Raw Materials (are they exploited as primary or secondary products?).

- Evaluate the impact of permitting processes in expanding existing or opening new mines.

- Evaluate quality (and purity) requirements and issues (materials from different mines/processes can have different characteristics).

- Evaluate environmental (life cycle) and social impacts.

- Evaluate importance of recycling today, gap analyses in recovery and recycling technologies. The costs of recycling and impacts of legislation.

- Evaluate LCA impacts, variations by region, source, refining processes and other parameters.

- Review existing (and ongoing) recycling processes and collection of materials for recycling, obligations (legislation), costs.

- Define and analyze scenarios for future requirements and needs for CRMs for EVs.

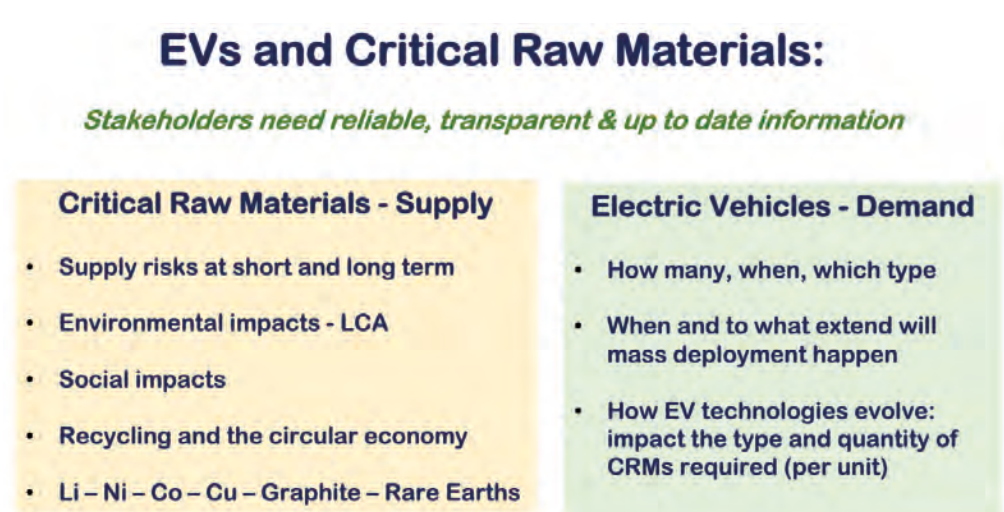

Figure 2: Key supply & demand issues for raw materials important for electric vehicles

RESULTS

Workshops and site visits

WORKSHOPS

The Task has held 3 workshops and 5 webinars so far. The planned workshop for June 2020 at Argonne National Laboratory (US) had to be cancelled due to the COVID pandemic and has been replaced by a series of 3 webinars.

- Workshop 1: November 2018, Brussels, hosted by Umicore
- Workshop 2: May 2019, Lyon, hosted by AVERE at the EVS32
- Workshop 3: November 2019, Shanghai, hosted by Botree, CAS-IPE &
- Site visits: 9-12th November 2019: Huayou Cobalt, AIWAYS EV manufacturer and CATL (Li-ion battery manufacturer).
- Workshop 4: series of 3 open webinars: June 9, 10, 11, 2020, hosted by Argonne National Laboratory (USA).
- Workshop 5: 2 open webinars March 17, 18, 2021, hosted by AVERE.
- Workshop 6: October 19, 2021, hosted by AVERE (virtual).

Attendance of the workshops was 30-40 people (each) from Task 40 CRM4EV participants and external experts and companies. The webinars were open to the public and had an attendance of 80–190 people.

Task 40 CRM4EV presentations at external conferences, events, and webinars

The IEA HEV Task 40 CRM4EV results have been presented at around 20 external conferences, events and as of 2021 in webinars. In 2021, Task 40 results have been presented (virtual) at the Suining Lithium Conference (China) and the AVERE European Conference.

Market developments 2020 - 2021

In 2020, many governments and EU (partly as part of “green” Covid recovery plans) as well as OEMs targeted (much) higher EV ambitions; BEV car sales 2020 was up 33% compared to 2019 – despite a 23% lower global car sales - PHEV sales grew even stronger. In 2020, LFP batteries have seen a “comeback” with developments from CATL, BYD and others to increase the capacity density. Tesla is currently using LFP batteries in the Model 3 and Y standard range models produced in China.

In 2021 EV growth has accelerated and BEV (car) sales have increased 110% compared to 2020. Large scale recycling of EV batteries is being introduced and further developed by a large number of companies. Legislation and policies for the recycling of EV batteries and the recovery of the battery metals is (being) implemented in China and the EU. In 2021, CATL has announced the development and upcoming commercialisation (2023) of Na-batteries for EVs, thought not possible before the next decade.

Task 40 CRM4EV scenarios and analyses

CRM4EV developed in 2019 growth scenarios for BEV cars: 20, 30, 40% growth year on year with 30% as the mid-range "target" scenario. In 2019 most external forecasts were in the low 20's % growth, 30% was perceived as "too optimistic, not realistic". In 2020 forecasts trended towards 30% growth per year. Task 40 CRM4EV developed in 2019 battery chemistry scenarios for BEV cars: a dominance of nickel-based chemistries and a trend towards higher nickel, low cobalt chemistries; no alternatives for lithium-based chemistries before 2030-2035; solid batteries with lithium metal anode entering larger scale commercial applications between 2025 and 2030. In 2021 the scenarios were extended to include significant growth in zero nickel and cobalt battery applications.

EV market 2030: external forecasts and CRM4EV scenarios

In 2021 a review has been made of the 2030 forecasts from organizations like IEA, Global Battery Alliance and major consultancies. The current – sort of - consensus view which appears from the analysis of these 2030 forecasts a 30% penetration (of BEV cars), or 30 million BEV cars sold, high nickel batteries remaining (by far) the dominating technology for EVs. According to our experience and work BEV growth as forecast for 2030 may very well be underestimated. To attain a 30% BEV (cars) penetration rate in 2030 requires only a 23% year-on-year growth whereas the actual growth rate is much higher, over 50% per year over the last 10 years and more than 100% in 2021. For other (heavy duty) vehicles, a very low penetration rate (less than 10% of sales) is forecast for 2030. Here we also expect a much higher penetration as full electric trucks are already cost-competitive in many cases, a trend which will further increase, and which will also increase the overall demand for batteries for electric vehicles. In figure 3, the CRM4EV scenarios for EV penetration are compared with the two major IEA scenarios for 2030.

Figure 3: Road vehicle and electric road vehicles 2020 market and 2030 scenarios. 2020: sources OICA, (US light trucks are in PC); EV data source Valuad); 2030 estimates CRM4EV (sources BNEF, own estimates) and IEA scenarios; CRM4EV scenarios YoY BEV growth rates 2020 - 2030: 30%, 40%, 50%. The IEA scenarios include minibuses and some light truck categories in the category MDV/HDV, commonly these are included in the LDV category.

Global (electric) vehicle markets 2020 - 2030 (sales in millions)

	2020 market	2030 market					
Vehicle category	vehicle sales	kWh per vehicle	CRM4EV BEV LCV 30% YoY vehicle sales	CRM4EV BEV LCV 40% YoY vehicle sales	CRM4EV BEV LCV 50% YoY vehicle sales	IEA STEPS vehicle sales	IEA SDS vehicle sales
Light Duty Vehicles (LDV)							
Passenger Cars (PC)	83		100	100	100	130	114
Light Commercial Vehicles (LCV)	8		10	10	10	18	17
LDV motorisat *ICE*	85		64	36	0	123	86
BEV	1.6	65	36	69	110	17	33
PHEV	0.6	15	10	5	0	8	12
Hybrid	3.5	2					
Heavy / Medium Duty Vehicles							
HDV/MDV (total)			5.4	5.4	5.4	12.3	13.9
Buses	0.5		0.6	0.6	0.6	1.1	1.2
Trucks	4.2		4.8	4.8	4.8	11.2	12.7
e-Buses	0.1	300	0.4	0.5	0.6	0.5	1.1
e-Trucks		500	0.8	1.2	2.4	0.2	0.5
PHEV e-Trucks						0.1	0.5
Vocational	0.5	300	0.1	0.1	0.3		

Battery and key mineral demands 2030

For the external (GBA, IEA, EV30@30) scenarios analyzed, the EV sales forecasts translate in a 2,500 - 3,500 GWh Li-ion battery demand for transport with mineral requirements of 1.5 million tons of nickel, 260-290 kton cobalt and 380 kton lithium (metal).

Summary of 2030 scenarios		Units	30% growth CRM4EV	40% growth CRM4EV	50% growth CRM4EV	GBA base	GBA target	EV30@30 midpoint	IEA STEPS	IEA SDS	BNEF	Road transport 100% electric "COP 21"
Batteries GWh												
	For transport	GWh	3142	5559	8905	2332	3389	2651	1490	2980	1322	10230
	Total for EV, ESS & CE	GWh	3432	5849	9195	2622	3679	2941	1687	3305	1612	10520
	Li-ion for transport	%	*92*	*95*	*97*	*89*	*92*	*90*	*88*	*90*	*82*	*97*
Mineral demand (CRM4EV modelling & scenario data)												
Nickel	Current assumptions chemistries	kton	1591	2786	4400	1003	1398	1365	767	1463	706	4924
	Ni demand external scenarios	kton				1061	1584		657	1584		
	High Mn chemistries	kton	1113	1854	2920							3444
	LFP + High MN	kton	563	929	1401							1487
Cobalt	Current assumptions chemistries	kton	257	454	719	191	274	220	129	251	111	805
	Co demand external scenarios	kton				214	290		109	263		
	High Mn chemistries	kton	293	517	820							918
	LFP + High MN	kton	150	266	411							427
Lithium	All CRM4EV Li-ion scenarios	kton	388	661	1039	243	330	332	177	346	182	1189
	Li demand external scenarios	kton				164	378		164	378		

Figure 4: Current public global scenarios for battery and key mineral demands 2030 compared to CRM4EV scenarios and the COP21 (100% zero emission transport by 2050). The mineral requirements are based on CRM4EV modelling or taken from the different scenarios (underlined data)

In Figure 4, the outcomes for the various external and CRM4EV scenarios for battery demand and key mineral demand are provided. To meet demand of certain critical minerals, significant impacts and risks will occur (supply, environmental, social, cost, geopolitical). Any "faster than anticipated" BEV growth will exponentially aggravate the impacts of the supply chain.

Nickel demand will outstrip supply according to our analysis in most external scenarios. Based on expert input, we estimate a maximum of 1.2-million-ton nickel extra available for batteries by 2030.

We expect LFP and other low nickel (high manganese) chemistries to play a much more important role than generally expected. LPF batteries have a lower cost, longer lifetime, safer, and a lower environmental footprint. This will likely provide an attractive alternative more since with the improving storage density of LPF. In our view also the rapidly increasing fast charging networks will reduce the need for large battery capacities. In our scenario where 50% of the batteries for transport are based on zero nickel & cobalt and a significant part of the remainder on high manganese chemistry, the expected demand of nickel can be met.

Solid state batteries are likely to become relevant faster and more significantly than projected currently. In our view, reaching a 20 to 40% market share by 2030 is possible. Advantages are lower weight, higher storage density, less materials, safer and a (much) higher fast charging capability.

The potential of sodium (Na) to replace lithium partially / substantially / mainly will become clear in this decade and commercial application will start in a few years. Although lithium is widely available, the current mining capacity is limited and will require a large effort to keep pace. Even a partial replacement of lithium with sodium will have a large impact. The "holy grail" for batteries for transport using none of the potentially critically materials like lithium, nickel, cobalt but also graphite or manganese seems to be in reach!

Ongoing activities

Finalization of the environmental (LCA) impact analysis and the evaluation of the recycling processes of Lithium-ion.

Using the updated battery chemistry development scenarios, raw material demand scenarios for 2030 will be made.

Regular communication on key global developments in the area of EV demand and key developments for relevant raw materials is also part of the Task 40 output.

NEXT STEPS

An update of the battery technologies and chemistries paper is currently being made as the developments and insights change rapidly.

The raw material scenarios will be further developed as well to reflect the changes in battery chemistries, use, and the development on the electric vehicle demand side. The work on e-motor raw materials and especially the rare earth metals will be finalized. The impact of EVs on the reduced use of PGMs will be finalized as well.

Overall conclusions of Task 40 work and policy recommendations will be made as part of the final report.

Task 40 CRM4EV will continue to be presented at seminars and a plan has been made to return to face-to-face meetings. The Task 40 CRM4EV closing event is scheduled (but not yet confirmed) for June 2022 to coincide with EVS 35 in Oslo, Norway.

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TASK 41

Electric Freight Vehicle

MEMBER COUNTRIES
AUSTRIA
GERMANY
REPUBLIC OF KOREA
SWEDEN
SWITZERLAND
UNITED KINGDOM

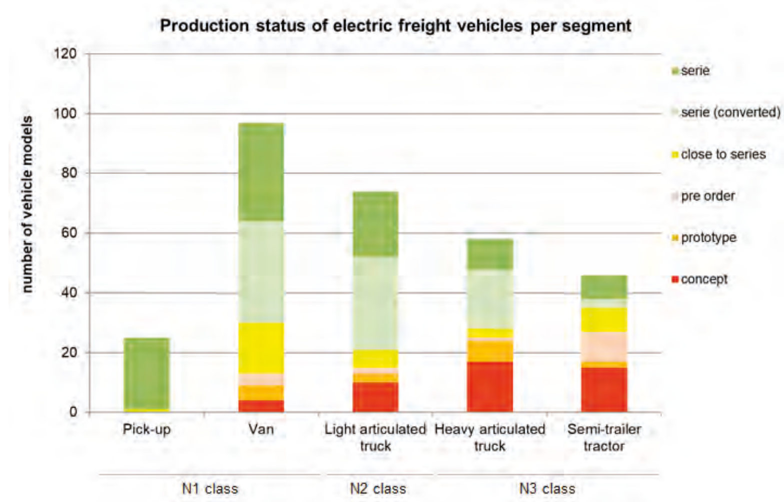
INTRODUCTION

Road freight transport is one of the fastest growing modes of transport and has an increasing share in the total GHG emissions of transport. Global trends such as growing population, urbanisation, and booming e-commerce have almost doubled the worldwide road freight activity and energy use in the last two decades[1]. Furthermore, higher gradients are observed for freight emissions compared to passenger travel emissions for most of the IEA countries[2]. Consequently, emissions standards for vehicles are defined in different countries. The European Union set fleet targets for average CO2 emissions for light and heavy freight vehicles aimed at reducing the increase in freight emissions[3]. Various technical and non-technical options exist for reducing the GHG emissions of road freight transport, such as improving the efficiency of freight logistics or fuel consumption performance of vehicles. Current emphasis is on incremental technology developments to reduce fuel consumption of conventional vehicles. However, there are potentials for (near) zero tailpipe emission vehicles that could result in the large-scale GHG reduction that is needed. In addition to global impacts, air pollutants are emitted locally through combustion of fossil fuels. This is a major problem in densely populated cities since road freight transport is responsible for the last mile delivery. Alternative delivery concepts can have an important contribution to sustainable urban logistics.

Prospects of battery and fuel cell electric freight vehicles

The IAA Commercial Vehicle Fair in 2018 characterized an increasing electrification strategy for commercial vehicles. Different manufacturers showcased their first battery-electric vehicle models. Especially in the Light Duty Vehicle (LDV) segment, battery-electric vans are already in series production. First BEV prototypes have also been introduced for the medium and heavy-duty segments and are currently being tested in various pilot projects with customers. Figure 1 shows the production status of different battery-electric freight vehicles per segment. The number of vehicle models available in series production decreases as the gross vehicle weight increases (hence from N1 to N3). Thus, the current battery-electric vehicle models in the heavy-duty vehicle segment are more in a conceptual phase (low production-readiness level). This is partly due to the demanding requirements of long-haul transport.

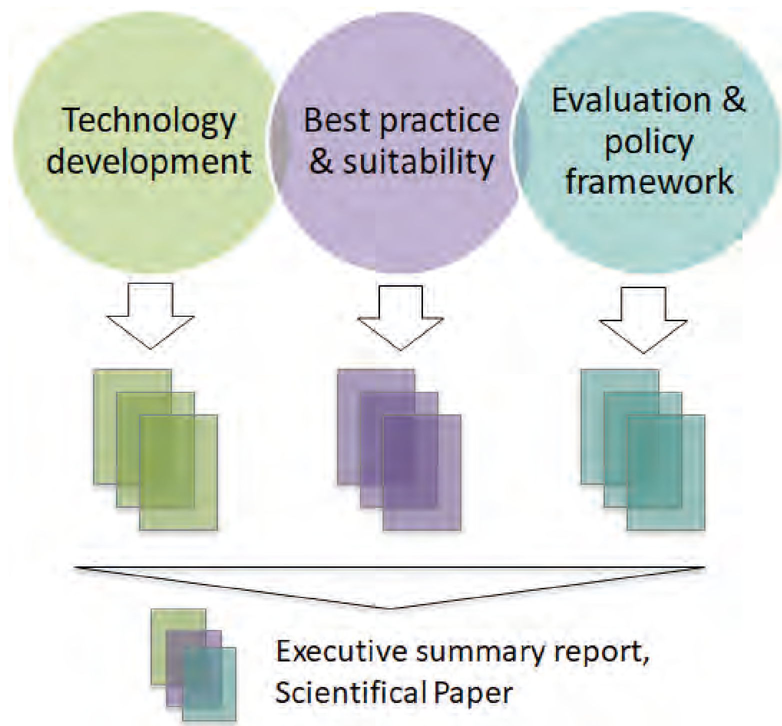
Figure 1: Market overview battery-electric freight vehicles 2020 - Availability of battery-electric freight vehicles by segment and production status (Status mid-2020)



OBJECTIVES

The tasks main objectives are to monitor progress and review relevant aspects for a successful introduction of electric freight vehicles (EFV) into the market. Three focus areas are included for this purpose:

Figure 2: Program of work



The first area "technology development of EFV" addresses the technical viability of EFV. Based on available EFV on the market, performances as well as standards and norms for EFV are described to monitor technical advances of EFV. The development of the charging infrastructure, particularly regarding costs and availability, is also in focus.

The second area of interest deals with "best practice and suitability aspects of EFV" to identify potential application areas for EFV. Successful examples of EFV implementations will be described based on best practice pilot projects. This includes an analysis of their opportunities and barriers for market introduction.

The third area looks at demand-side issues and is linked both to end customers and to policies. Given the different suitability of EFV technologies for replacing conventional diesel engines, economic and ecological aspects of EFV will be evaluated. By using existing models, Total Cost of Ownership and CO2-emission calculations for promising “vehicle - transport task” combinations are undertaken.

The topics of each focus area are presented in the form of short fact sheets, which will provide the base to review the aspects for a successful introduction of EFV into the market.

The scope of Task 41 includes vehicles of the size classes N1, N2, and N3 and all types of electrified or electric powertrains like hybrid, plugin-hybrid, battery-electric, fuel cell electric and electric road powertrains.

WORKING METHOD

The working method comprises desk research, workshops, and public outreach. The main approach is to collect and exchange information in workshops and through contacts to other international networks. According to the objectives, the workshops are aimed at professionals from manufacturers, TIER1 suppliers, researchers, project managers, city planners, policymakers, and other stakeholders. The topics and the individual orientation of the workshops are determined by the task partners. There are both public and non-public workshops planned. Individual contributions/sessions can be treated confidentially at the request of the participants. It is expected that the partners actively participate in the workshops.

Desk research will provide information for discussion e.g., on vehicle technology and cost developments, and are presented in several fact sheets. The desk research should be reflecting a networking activity by the exchange of information and answers to questions from participating members.

Public outreach activities such as presentations, scientific publications and flyers will be prepared to disseminate the findings to a wider audience.

RESULTS

The electrification of freight is a direct response to the requirement to reduce the GHG emissions from road transport. The challenge has been to introduce electrification whilst continuing to meet the user requirements. This has given rise to numerous activities in the different vehicle segments of the freight sector with some uncertainty as to which solutions will be adopted in the longer term. In response to the challenges, the activities within Task 41 resulted so far in the following products:
1st Workshop on EFV in urban logistics

The first Task 41 workshop, “Battery-electric freight vehicles in urban logistics," was held in Stuttgart (Germany) on October 15th, 2020. Dedicated topics of the workshop were: current technical characteristics of battery-electric freight vehicles, development of the charging infrastructure and practical experience and knowledge from pilot projects. Twenty-four local and international guests from logistics as well as logistics associations, vehicle industry, charging infrastructure, city administration and research took part in the discussion on opportunities and hurdles for the successful implementation of battery-electric freight vehicles in urban logistics. The main topics of the discussion were the still ongoing uncertainty in battery electric as well as fuel cell technologies, the lack of space for electric charging stations and loading stations in urban areas, and the uncertainty about necessary charging capacities for different transport applications. Furthermore, the discussion with the participants showed that it could be very useful for the logistic and fleet operators to learn more about current applications with battery-electric freight vehicles, including information on their total cost of ownership.

Figure 3: Task41 Workshop, October 15th 2020 in Stuttgart

2nd Workshop on EFV in long haul transport

On September 29th, 2020, the Task41 team hosted the 2nd online workshop/webinar on "Electrification of Heavy-Duty Vehicles in Long Haul Transport". In three sessions experts shared and discussed the present state of technologies, experiences, and best practices–covering alternatives including fuel cell electric, battery-electric and catenary electric freight vehicles. In total, thirty-four attendants from industry, research, logistics and governmental organizations joined the webinar.

Essential for the implementation of electric freight vehicles in long-haul transport are the new developments in battery and fuel cell technology. Akasol AG predicts that the energy density of their high energy batteries for commercial vehicle applications would likely increase from 140 Wh/Kg today to 240 Wh/Kg until 2024. For their high-power batteries, which are especially suitable for fast charge and hybrid power applications, Akasol expects the charge capacity to increase from 500 W/Kg today to 800 W/Kg in 2024. However, many manufacturers and vehicle retrofitters such as the Quantron AG criticize the present limited availability of battery cells. Quantron AG proposed that the European market needs a commitment for battery supply of five to ten years before. As an alternative, or as an adjunct to the battery for energy storage, there is also the option of a fuel cell. This is viewed as attractive for the long-haul freight sector. However, there is a cost issue to overcome. To be successful with the deployment of any alternative, it is essential that the necessary infrastructure is established in parallel with vehicle market development and that it is adapted to the specific application fields/tour profiles. E.g., ultra-fast charging station on highways for battery-electric heavy-duty vehicles.

In the discussion session, the International Council on Clean Transportation (ICCT) stated that access to capital is one of the key barriers they have seen in the past for fleets to invest in efficient technologies. Thus, it will require innovative financing solutions to ensure that the barrier of upfront cost and the access to capital can be overcome and depreciate over the vehicle operation time.

3rd Workshop on Electrifying Road Freight – Overcoming the Diesel Vehicle Mindset

The third Task 41 workshop, "Electrifying Road Freight–Overcoming the Diesel Vehicle Mindset," was a jointly hosted online event together with the Taskforce 45 of the HEVTCP. The workshop took place from December 7th to 9th, 2021 with 46 participants in total from North America, Europe, and Asia, in addition to stakeholders from the road freight sector, including energy providers, government actors, researchers and NGOs. The event was structured in the form of a webinar with expert-led presentations and panel discussions. The introductory statement of the three-day workshop was that for the electrification of the road freight system, the current diesel vehicle mindset needs to be overcome. This was in recognition that the system in which new technology is to be deployed needs to be adapted accordingly if that new technology is to be successful. Therefore, Day 1 of the webinar focused on identifying the system challenges. For this purpose, different stakeholders from political, environmental, societal, technical, economic, and legal areas shared their views and discussed the question on system challenges. The next day was characterized by presentations on solutions for electric road freight innovation systems. The selection of presentations was based on covering the gamut of solutions - from technology to user-based. On day 3, participants were asked to evaluate the suitability of solutions (discussed day 2) in the context of the challenges identified (discussed day 1) and concluded with an open session on identifying how governments, logistics, and industry can be mutually supportive in moving on from the present diesel mindset in freight. In parallel to the 3-day event, a survey was carried out. A detailed summary of the results of the workshop will be published at the next International Electric Vehicle Symposium & Exhibition in May 2022 (abstract submitted).

Fact sheet on the State of the Art of Electric Freight Vehicles

The main challenges in the technical performance of Electric Freight Vehicles (EFV) are the available range, payload and charging time today. The traction battery has a major influence on the indicators. In addition, the limited availability of EFV models and the rapid technological development plays a major role in the attractiveness of EFV in the market[4]. However, the market is developing rapidly. The question, therefore, arises whether the current state of performance of EFV is competitive with a conventional freight vehicle today.

In the task41 fact sheet, "The State of the Art of Electric Freight Vehicles," different technical indicators for EFV were evaluated. Figure 4 compares the vehicle and market specifications of diesel, battery-electric and fuel cell-electric vans in 2020. The information was obtained from the Task41 vehicle database. The comparison shows among others that battery-electric vans for the considered use case (urban delivery) can have a lower TCO (Total Cost of Ownership) in diesel vans. With the rapid development in battery technology, further technological improvements in terms of range and payload of freight vehicles can still be expected. The fact sheet is available for download on the HEVTCP website[11].

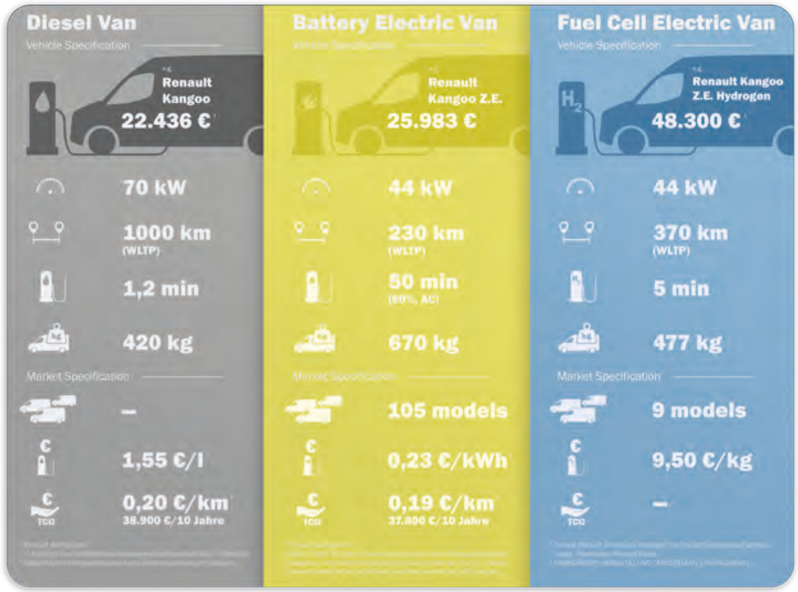


Figure 4: Comparison of diesel vans with battery-electric and fuel cell-electric alternatives in 2020

Fact sheet on the European Truck Market and Potential Powertrain Technologies

Figure 5 illustrates the European light and heavy-duty vehicle market in 2019. Eight selected countries are shown, representing about 75% of the European light or heavy-duty vehicle stock. In 2019, 2.48 million Light and Heavy-Duty Vehicles were newly registered in Europe, 85% of which were Light-Duty Vehicles (LDV) under 3.5 tons gross vehicle weight (GVW). Most of the vehicles are powered by a diesel engine (92.8% LDV, 97.9% HDV). Alternative fuels, like CNG, LPG, biofuels, and ethanol, had a share of approximately 1.4% in the overall commercial vehicle registration in 2019. The market niche is made up of Hybrid Electric Vehicles (HEV) with 0.2% of new registrations. However, the market share in the LDV has risen to almost 160% compared to the previous year (4,577 hybrid-electric vans in 2019). Another high increase was recorded by plug-in electric commercial vehicles (BEV, FCEV, REEV, PHEV) with 26,107 plug-in electric LDV and 747 plug-in electric HDV newly registered in 2019. The year-on-year increase was stronger in the HDV segment (+109%) than in the LDV segment. The main markets for these vehicles are primarily Germany, followed by the Netherlands and France.[5,6]

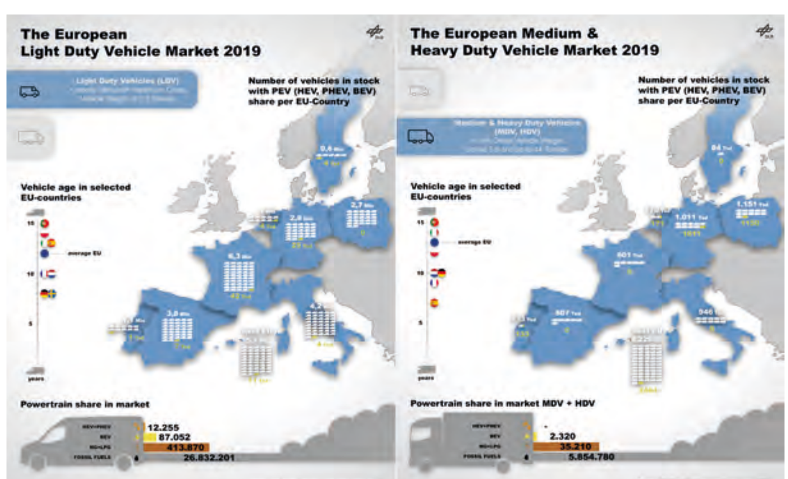


Figure 5: The European light and heavy-duty vehicle market in 2019

Source: see reference 7

In the media, the first long-term strategies of the manufacturers have appeared with information on the planned investments. The task41 fact sheet, "The European Truck

Market and Potential Powertrain Technologies," gives an overview of the known short- and long-term powertrain strategies of the OEMs. As a summary, the market developments show that electrification efforts are beginning to take hold in the entire commercial vehicle segment. However, compared to the passenger car market, the manufacturers' strategies differ in some respects. The full fact sheet can be found on the HEV-TCP website[12].

Fact sheet on evaluating powertrain and fuel options for heavy-duty vehicles to meet the EU CO2 emission fleet targets

In this fact sheet, current and future energy, and emission consumption of conventional and alternative powertrain systems in heavy-duty vehicles on long-haul transport are compared and weighed regarding the EU CO2 emission fleet targets. The analysis was developed in the framework of cooperation between the two IEA TCP AMF Annex 57 and HEV task41. AMF Annex 57 "Heavy Duty Vehicle Evaluation"[8] aimed to demonstrate and predict the progress in the energy efficiency of heavy-duty vehicles with internal combustion engines and alternative fuels technologies. The full fact sheet can be found also in the AMF Annex 57 report[13].

The simulated CO2 emission of the different powertrain and fuel options are compared to the EU CO2 emission reduction targets, with -15% in 2025 and -30% in 2030 relative to 2020[3]. The reference values for the comparison are the simulated WtT and TtW CO2 emissions of the diesel HDV in 2020. The simulated values are given for 2020, 2025 and 2030, describing anticipated progress.

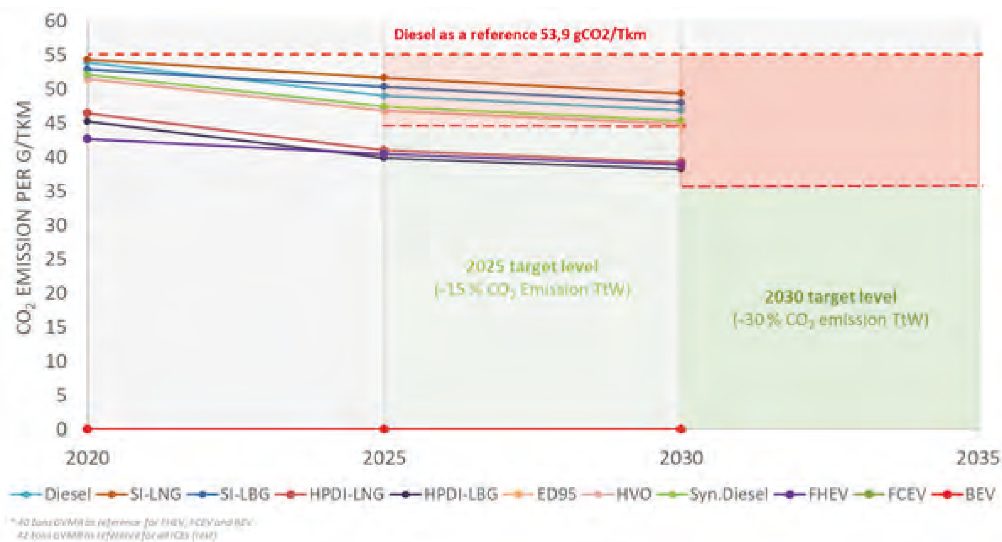


Figure 6: TtW CO2 emissions in g per ton-kilometer for different powertrain and fuel options

Figure 6 shows the development of the calculated TtW CO2 emission per ton-kilometer for different powertrain and fuel options until 2030. TtW (tailpipe) CO2 emissions are used as the basis for all vehicle CO2 regulations today[9]. FCEV and BEV do not emit tailpipe emissions. Thus, this option meets the 2025 and 2030 targets for TtW CO2 emission reductions. Figure 6 shows minor differences in terms of the internal combustion engines (ICE) fuels: fossil diesel, synthetic diesel, HVO (biodiesel), ED95, but also spark-ignited LBG and LNG. The calculated TtW CO2 emissions per Tkm of these vehicle configurations in 2025 are above the EU CO2 emission limit. The TtW CO2 emissions between different fuels (diesel, HVO, ED95, syn-diesel) are slightly different in CI-engines depending on the fuel's carbon to hydrogen balance (CO2 intensity of the fuel). The only pure ICE powertrain alternative that achieves the 2025 target with a margin is HPDI LNG/LBG. Also, FHEV-Diesel meets the 2025 target with a margin, but not the 2030 target level.

Figure 7: WtW CO2 emissions in g per ton-kilometre for different powertrain and fuel options

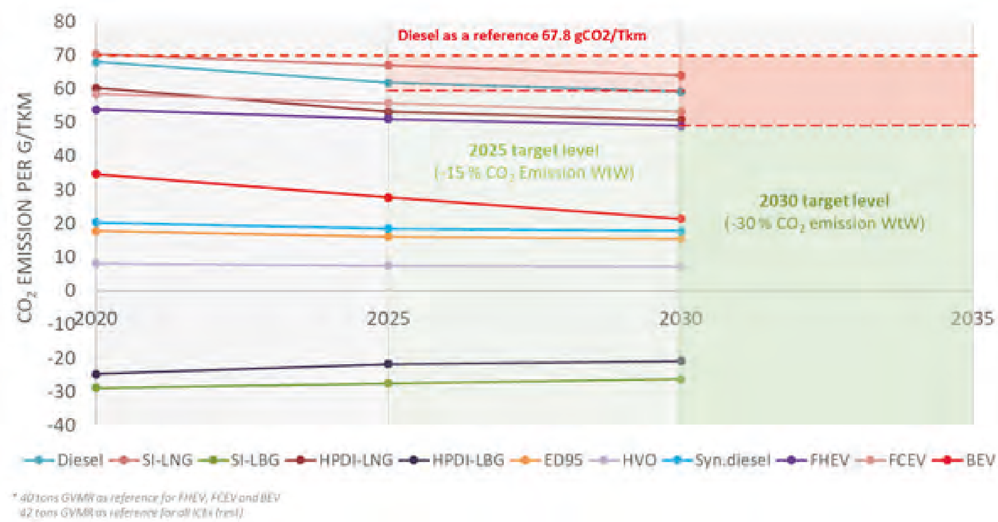


Figure 7 shows the development of the calculated WtW CO2 emission per ton-kilometre for different vehicle configurations until 2030. In this figure, both upstream (WtT) and end-use (TtW) emissions are considered. The analysis again assumes that reduction targets are -15% and -30%, relative to 2020 fossil diesel, but on a WtW basis. As stated above, the WtT values stem from the JEC Well-to-Tank report v5 which considers reference values for each corresponding fuel. The only alternatives that cannot meet the 2025 target of -15% are diesel (fossil) and SI-LNG (fossil). HPDI-LNG, FHEV and FCEV on hydrogen from fossil natural gas meet the target, but with a small margin. All renewable alternatives (ICE) and BEV on the predicted EU 2030 electricity mix meet the 2025 target with a wide margin, as they also meet the 2030 target of -30%. Consequently, the fossil alternatives HPDI-LNG, FHEV (on diesel) and FCEV (on hydrogen from natural gas) do not meet the 2030 target.

NEXT STEPS

Task41 members are actively participating in the regular UK commercial vehicle working group (UK CWWG) meetings and the regular meetings of the international action group "Call for Zero-Emission Freight Vehicle" (an initiative of the Transport Decarbonisation Alliance)[10]. Task 41 will continue the active participation in the ongoing working groups.

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4. Quak H, Nesterova N and van Rooijen T 2016 Possibilities and Barriers for Using Electric-powered Vehicles in City Logistics Practice Transportation Research Procedia 12 157–69

5. ACEA 2020 Fuel types of new trucks: diesel 97.9%, electric 0.2%, hybrid 0.1% market share in 2019

6. ACEA 2020 Fuel types of new vans: diesel 92.8%, electric 1.2%, alternative fuels 1.3% market share in 2019

7. Özcan Deniz 2020 The European Truck Market and future powertrain technologies: IEA TCP HEA Task 41 Fact sheet (IEA HEA-Task41)

8. IEA-AMF 2021 Heavy-Duty Vehicle Evaluation: Purpose, Objectives and Key Questions https://www.iea-amf.org/content/projects/map_projects/57 (accessed 19 Feb 2021)

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12. http://www.ieahev.org/assets/1/7/Task41_factsheet_market_forecast.pdf
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TASK 45

Electrified Roadways (E-Roads)

MEMBER COUNTRIES
AUSTRIA
GERMANY
ISRAEL
THE NETHERLANDS
NORWAY
SWEDEN
SWITZERLAND
UNITED STATES

INTRODUCTION

Task 45 is primarily an information gathering and research documentation effort, focused on the complimentary technologies, standards, and the various challenges and applications of Electrified Roadways (E-Roads) also called electrified roadway systems (ERS).

E-Roads are defined as a combination of road infrastructure and technologies which allow for a vehicle to receive power (electricity) from an off-board source while the vehicle is in motion. This task has a broad scope of technologies and system deployments and will include E-Roads applications for light duty vehicles (LDVs), as well as commercial and transit vehicles.

The inventory of pilot deployments of E-roads continues to expand and the interoperability for the technology between vehicle classes and throughout international deployments are key focus topics of the project.

The task will provide information critical for decision makers who are considering E-Roads deployments and educate stakeholders of the progress of the various technologies. The task had its official kick-off meeting in June of 2021; there are currently 8 countries who are formally participating on the task.

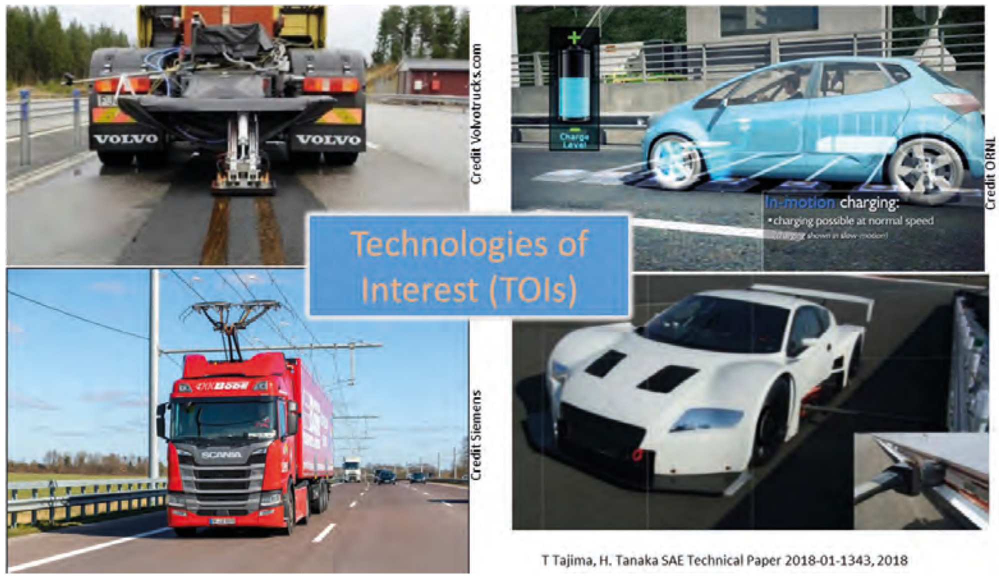
OBJECTIVES

Working with international companies, academic institutions, laboratories, and agencies, the task will develop a greater global understanding and awareness of E-Roads, related deployment activities, technologies developed to advance electric mobility. The task will gather information regarding national policy and the benefits/challenges related to E-Roads to gauge the global interest and commitment levels, and move to focus research efforts to solve the greatest challenges.

The four Technologies of Interest (TOI)s which Task 45 will focus on are:

- Dynamic Wireless Power Transfer (DWPT)
- Non-road Conductive (Overhead), which is separated into two sub-categories
- Non-road Conductive (Side)
- In-road Conductive

Figure 1: Task 45 TOIs



Task 45 will also monitor the progress of international standards (JARI, SAE, ISO/IEC, etc.), related to the various E-Roads technical approaches (listed above), as well as the integration of the power grid into the road infrastructure, and will gather pertinent cost information for deployments of the various technologies and power levels. Making this information available to all member countries through the member site will facilitate better decision-making regarding E-Roads by policy makers and municipalities.

WORKING METHOD

The task will conduct bi-annual meetings, which may include viewing locations of E-Roads research or deployment activities, to gain first-hand knowledge of how these technologies are progressing and to inform the HEV-TCP of advancements in E-Roads.

Based on information gathered from participating countries, specific topics may be identified as critical areas for further research. The member countries will report on related technology or analysis findings regarding the effectiveness of deployments or advancements in relevant technologies or safety & standards development.

Bi-Annual Meetings

The meetings and workshops coordinated by this task will focus on specific topics for each event. The order of workshop topics will be based on the priorities of the member countries and timing of related deployments.

The task members will:

- Develop an understanding of the challenges faced in various countries or markets by categorizing deployment approaches and requirements for E-Road technologies.
- Catalog and compare standards (JARI, SAE, ISO/IEC, etc.) in areas such as power transfer, alignment or other vehicle controls, data security, and communications.
- Summarize safety and operational issues arising from vehicle to E-Roads

systems connections and possible E-Roads systems connections to the electric grid.

- Develop an understanding of the vehicle technology requirements and optimized E-Roads deployment at scale. This unbiased information is critical for decision makers considering E-Roads deployments.
- Conduct comparisons of current technology development and address concerns for each of the TOIs.
- Generate a workshop report following each event to document findings, highlight progress or further identify gaps to E-Roads deployment at scale.

Members' SharePoint Site

Information and presentations from the workshops, as well as reports and other task products, are being stored in the Members' SharePoint Site.

The task members and appointed representatives from the member nations:

- Have full access to the site for reference materials, including previous workshop presentations, both from member and guest presenters
- Will support the data repository with input related to their countries or companies/organizational activities within the scope of the task. This may include active deployment information, field data, studies or other reporting methods

RESULTS

New member countries Germany, Sweden and Israel joined the task in 2021, and Austria committed to join the task later in the year. The membership stands at eight member countries, as Switzerland, Norway, The Netherlands, and the United States were active prior to 2021.

The formal kick-off of the task was held virtually in June of 2021. That event had five technology presenters and introductions from each of the six member countries that were active at that time, with 34 different attendees (including presenters) over the two-day agenda.

The second workshop was held in partnership with Task 41 (The Electrification of Freight Vehicles) in December of 2021. The 2nd workshop had 15 presenters spread out over three days, with an agenda that included numerous discussion panels and a white boarding session on the final day.

Due to recent travel and other operational restrictions, both of the first two meetings had a virtual format. The member countries meet monthly to discuss the progress and interest of countries who are active in the E-Roads space.

NEXT STEPS

The next workshop will focus on the business case for E-Roads and will be held in the summer of 2022. The workshop topic is broad, however the member country representatives have identified four main categories for presentations and discussion. This meeting is currently planned for an in-person meeting in mid-June of 2022, pending travel impacts/restrictions caused by the pandemic.

Business Model Development and Implications

a. Costs for construction, including electricity provision, charging system manufacturer/network operator, maintenance etc.
b. Carbon reduction or other impacts studies/formula
c. Owner of the road, and the construction/infrastructure company & legal power to the roadway
d. Payments system which bills road users; impacts of metering and billing in different technologies

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TASK 46

LCA of Electric Trucks, Buses, 2-Wheelers, and other Vehicles

MEMBER COUNTRIES
AUSTRIA
GERMANY
SWITZERLAND
SPAIN
UNITED STATES

ACKNOWLEDGEMENT
The work of the Austrian participation (2022 – 2024) is financed by the Austrian Climate and Energy Fund and the FFG.

INTRODUCTION

Electric vehicles (EVs) have the potential to substitute conventional vehicles to contribute to the sustainable development of the transportation sector worldwide, for example, in the reduction of greenhouse gas (GHG) emissions, fossil energy consumption and particle emissions. There is international consensus that the improvement of the sustainability of EVs can only be analyzed based on life cycle assessment (LCA), which includes the production, the operation, and the end of life (EoL) management of the vehicles and the fuel cycle.

In recent Tasks 19 and 30 there was a strong focus on LCA of passenger vehicles and its comparison to gasoline and diesel vehicles. However, due to the strong development and market introduction of other battery electric vehicles, this new task will focus on LCA of other battery electric vehicles (BEV) than passenger cars and will also compare the environmental effects it has to other fuels made from electricity like hydrogen and e-fuels. These are hydrogen fuel cell vehicles (H2-FCV) and internal combustion engines using e-fuels (e-fuel ICE).

OBJECTIVES

The new IEA HEV TCP Task 46 (2022 – 2024) "LCA of electric Trucks, Buses, 2-Wheelers, and other Vehicles" started in January 2022.

The main objectives are (Figure 1)

- Stakeholder involvement in three expert workshops
- Technology and system description with vehicle and infrastructure data, relevant issues and LCA data on buses, trucks, 2-wheelers, and other vehicles with different fuel/propulsion systems
- Case studies on LCA of
    - Buses (urban and rural)
    - Trucks (from delivery truck to huge trucks incl. overhead line)
    - Two-wheelers
    - Other vehicles e.g., mining trucks (e.g., in ore mining Erzberg/Austria)
- LCA comparison to renewable hydrogen, e-fuel systems, and conventional fuels (Figure 2)

- Assessing “climate/CO2-neutrality” and “circularity” in a LCA perspective and methodology
- Dissemination and publications, e.g., presentations/contribution at conferences, Contributions to Annual Report and newsletter
- Identify R&D demand

Figure 1: Main objectives of Task 46

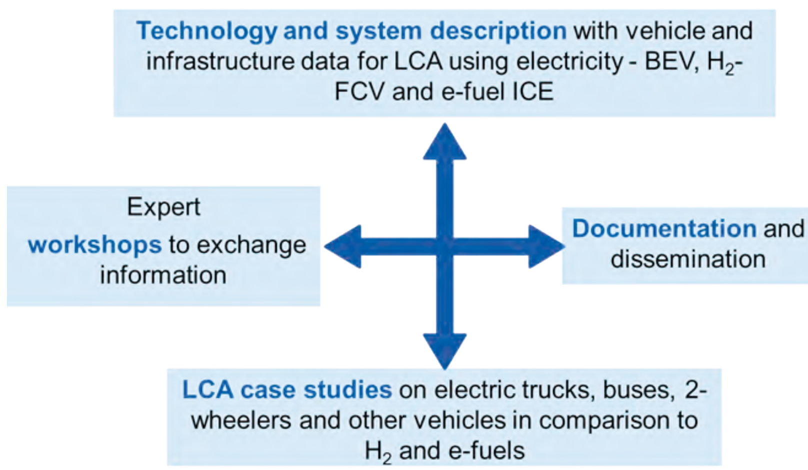
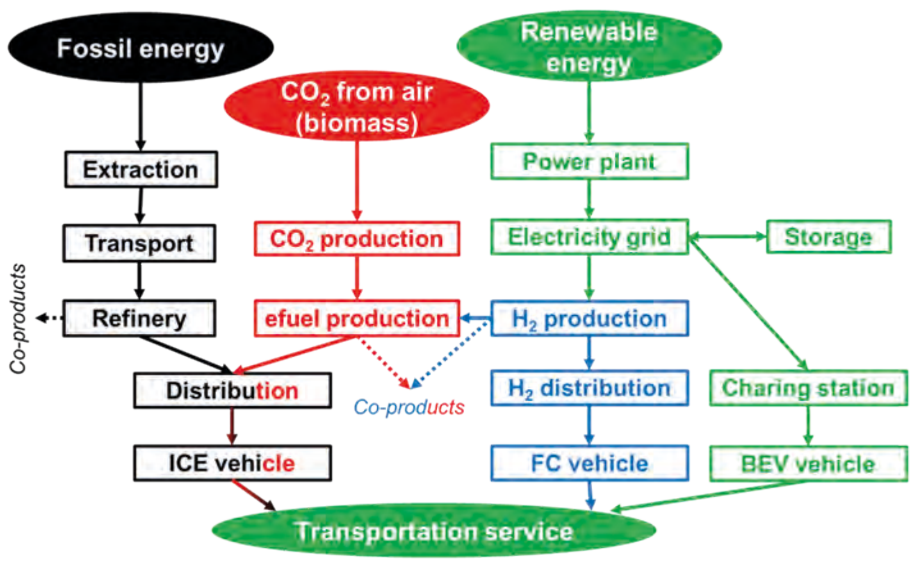


Figure 2: LCA comparison to renewable hydrogen, e-fuel systems, and conventional fuels



WORKING METHOD

Within Task 46, methodologies are developed to help countries implement EVs by identifying possibilities to maximize the environmental benefits. Besides, various case studies are analyzed, and networking combined with information exchange is supported within the Task’s frames.

The Task proceeds by organizing a series of expert workshops covering the objectives described above with a focus on:

- LCA of e-Trucks
- LCA of e-Buses
- LCA of e-2-Wheelers and other e-Vehicles

RESULTS

The task started at the beginning of 2022, so no results are available yet.

NEXT STEPS

The task will start with a kickoff meeting. Interested institutions in the HEV member countries are invited to join and contribute to this new task. The next step will be to make the technology and system description of the considered vehicles and their necessary infrastructure. In autumn 2022, the first expert workshop on "LCA of e-Trucks" will take place.

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TASK 48

Battery Swapping

MEMBER COUNTRIES
CHINA
GERMANY
ITALY

INTRODUCTION

On November 24, 2021, the HEV TCP Executive Committee officially confirmed the establishment of the "Battery Swapping" task group with China as the initiator and Botree Cycling taking charge of the implementation, which became the 48th task of HEV TCP: Battery Swapping.

The battery swapping mode has a long history dating back to 2007, when it was developed by Better Place, an Israeli company. For over a decade, the battery swapping mode has experienced failure and abandonment around the world and is not regarded as promising. However, in recent years, China has come to the forefront in battery swapping globally due to its huge and rapidly developing new energy vehicle market. Enterprises represented by NIO and Aulton are quickly gaining market recognition thanks to their advanced battery swapping technology and the well-designed business model of vehicle-battery separation. Nevertheless, the full promotion of battery swapping in the future still needs to leverage on the continuous exploration and breakthrough of battery technology, power grid facilities, and battery swapping business models. Therefore, the main purpose of task 48 is to study the impact of battery materials, grid infrastructure, environment, and business models on battery swapping technology, enhance the global exchange of information on battery swapping technology, help develop an ecosystem and traceability mechanism for battery swapping, and provide recommendations for policy makers and stakeholders.

OBJECTIVES

The main objective of this task is to investigate the influences of battery swapping employment on battery chemistry, grid infrastructure, environment, and business model, strengthen the global information exchange on battery swapping technology, help the formation of battery swapping ecosystem and traceability mechanism, and offer suggestions for policy makers and stakeholders.

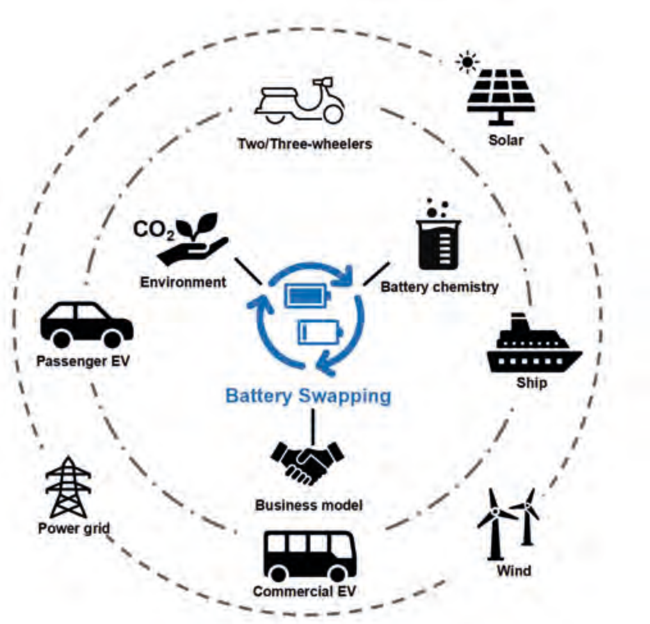

Figure 1: Task 48 target domain

Source: Botree Cycling

There have been massive arguments on battery swapping, some typical examples are:

- Non-uniformity and poor reliability of battery swapping interface
- Difficulty in unifying battery design/structure to achieve common use for different models
- Immaturity and high cost of battery swapping station construction
- Inefficient resource utilization due to lack of method to decide station location/ number of batteries equipped and charging time
- Responsibility partition in case of safety problems

This task will focus on the research and communication on the technology, application, standard and business model of battery swapping, analyzing battery assets whole life cycle management, and battery swapping technology evolution, while also shining light on the above-mentioned arguments.

WORKING METHOD

The task will cover battery swapping in the segments of two/three-wheelers, passenger cars, commercial vehicles, and ships. To achieve the main objectives, the following methods will be adopted:

Conducting survey and research

Survey and research on the status of battery swapping technology will be carried out in various countries and segments to get first-hand information of the industry and share the latest data and information.

Collaboration with existing task groups

Experience and information can be learned from the work from the below ongoing tasks:

- Task 30 Assessment of Environmental Effects of Electric Vehicles
- Task 32 Small Electric Vehicles
- Task 34 Batteries
- Task 38 Marine Applications (e-Ships)
- Task 41 Electric Freight Vehicles
- Task 43 Vehicle/Grid Integration

Establishing a project working group

This task will invite representatives from the industrial chain (e.g., battery manufacturers, automotive OEM, battery swapping station operator, battery asset management company) and research institutions from each member country to carry out relevant research work.

Organize international information exchange and seminar meetings

Conducted in the form of face-to-face or remote video, upstream and downstream stakeholders in the battery swapping industry will be invited to discuss technology development and explore business models.

Promote cooperation among members

Promote cooperative demonstration projects among member countries to exhibit the development of battery swapping technology and commercial operation models.

The operating agent will organize two conferences (one in summer and one in winter) per year with each conference lasting for 1-3 days. The conference can be held in different member countries each time, to facilitate technical demonstrations and plant visits.

RESULTS

This task was established in November 2021, and Germany and Italy have confirmed their participation. The detailed work will be carried out from 2022.

NEXT STEPS

Tasks to be executed (non-exhaustive):

- Investigate the latest status of battery swapping technology and analyze how it can help drive the development of the new energy industry, including battery, grid, and energy storage industries.
- Encourage and support the development and application of battery swapping technologies and promote the construction of demonstration projects for battery swapping plants.
- Define and reach consensus on battery materials and structures, battery swapping modes and interfaces related to battery swapping technology and provide references for the development of relevant international standards.
- Research the whole life cycle carbon footprint calculation method of power battery under the battery swapping mode, accumulate basic data, and establish a shared database.
- Carry out international technical cooperation, establish a global technical information exchange platform, and realize information sharing among industries and research institutions engaged in research on battery swapping technology.
- Establish a battery swapping ecosystem and explore a mature and sustainable commercial operation model.
- Research on the full life cycle traceability mechanism and block chain of batteries in the battery swapping mode.

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SECTION C

HEV TCP Worldwide

Overview of Hybrid & Electric Vehicles in 2021

HEV TCP Member countries report new Hybrid and Electric Vehicle passenger vehicle registrations and total numbers of these vehicle types registered (e.g. stock). Table 1 shows the total registrations for passenger vehicles of these vehicle types over the last three years. The country chapters provide more detailed numbers for 2021

	HEVS			EVs & PHEVS		
Country	**2019**	**2020**	**2021**	**2019**	**2020**	**2021**
Austria	44,010	59,582	107,111	37,060	68,286	106,402
Belgium	n.a	n.a	n.a	62,081	110,532	181,685
Canada	278,583	318,827	418,973	155,609	209,075	297,960
China	1,080,000	1,490,000	1,730,000	3,810,000	4,910,000	7,830,000
Finland	n.a	n.a	105,651	29,365	55,868	99,911
France	n.a	534,000	n.a	227,381	292,658	715,841
Germany	437,208	724,228	1,103,095	238,792	588,944	1,184,416
Ireland	47,586	n.a	85,072	14,859	17,990	44,976
Italy	244,484	n.a	964,918	44,825	99,519	235,676
Netherlands	210,642	261,400	342,270	203,419	292,240	381,327
Norway	110,665	n.a	115,924	376,610	486,037	647,691
Rep. of Korea	478,938	522,735	543,148	89,918	134,962	147,746
Spain	343,000	139,609	684,873	52,832	98,483	153,195
Sweden	66,609	122,290	152,738	147,855	186,195	299,675
Switzerland	92,061	126,175	185,061	49,642	83,329	139,540
United Kingdom	518,339	667,519	n.a	247,199	409,184	710,259
United States	5,374,023	5,800,523	6,435,669	1,443,637	1,741,530	2,322,291
Totals	**9,326,148**	**10,766,888**	**12,974,503**	**7,231,084**	**9,784,832**	**15,498,591**

Table Source: HEVTCP Annual Reports and the European Alternative Fuels Observatory (alternative-fuels-observatory.ec.europa.eu)

Austria

MAJOR DEVELOPMENTS IN 2021

NEW REGISTRATIONS OF ALTERNATIVELY POWERED PASSENGER CARS RISE AGAIN, DESPITE THE OVERALL TREND

In 2021, 239,803 new passenger cars were registered, 3.6% less compared to 2020. Thus, new passenger car registrations are 27.2% below the level of the pre-crisis year 2019 and have reached the lowest level in 37 years. The decline is linked to a continuation of the significant decrease in petrol and diesel-fueled passenger cars registrations. So fell the number of petrol-powered passenger cars to 91,478 corresponding to a share of 38.1% and the number of diesel-powered passenger cars to 58,263 corresponding to a share of 35.9%.

Despite the overall trend, the share of all alternatively powered passenger cars with 90,062 cars increased to 37.6%, thus showing an impressive 17.5 percentage points increase within a year. In absolute numbers, the figures are even more impressive, with an increase of 79.9% compared to 2020 with 50,060 cars. Among alternative drives, petrol-hybrid passenger cars (43,051) have a share of 18.0%, BEV passenger cars (33,366) one of 13.9% and diesel-hybrid passenger cars (13,545) one of 5.6%.

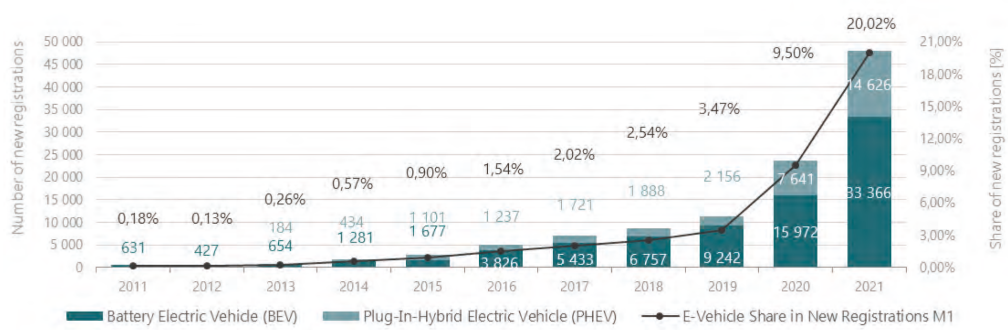


Figure 1: Development of BEV/PHEV new vehicle registration in Austria (2011-2021)

Source: Statistik Austria, Image courtesy of AustriaTech[1]

New policies, legislation, incentives, funding, research, and taxation

Austria offers a broad set of supporting instruments for the e-mobility uptake, such as purchase subsidies, registration tax benefits, ownership tax benefits, company tax benefits, VAT benefits, infrastructure incentives, or free parking. Austria co-operates with the European Alternative Fuels Observatory[2] [CF1] (EAFO), where an overview of the Austrian instruments is available.

»RIGHT TO PLUG« - LEGAL SIMPLIFICATIONS FOR THE INSTALLATION OF CHARGING INFRASTRUCTURE

On 1 January 2022 the »Right to Plug«, a package of legal simplifications in the decision-making process for communal installations and in the required consent for individual installations, came into force. This will help increase the number of charging points, especially in urban areas where public space is scarce. This legal change is a prerequisite for the eMobility uptake, as in the past the installation of charging stations in apartment buildings was permitted, but often failed in practice due to difficulties in obtaining the consent of the other co-owners.

RESEARCH AND INNOVATION – AUSTRIAN NATIONAL BATTERY INITIATIVE AND M-ERA.NET ACTIVITIES

The development and production of battery cells, modules and packs, and electric vehicles is of utmost importance for Austria due to its strong automotive supply industry. Hence, the Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK)[3] set up the Austrian National Battery Initiative[4] in close cooperation with industry and research. The initiative covers the whole value chain, from raw materials to the production of battery cells, up to the module and battery pack and its integration in the vehicle. It includes recycling and sustainability in energy and battery production, as well as efficient industry 4.0 processes. Up to the end of 2021, three battery calls have been published.

In addition, 2021 Austria contributed to a call on batteries in the M-ERA.NET, which allows to fund ambitious transnational RTD projects. With the participation in the M-ERA.NET Austria strives to overcome national research barriers and to intensify transnational cooperation with over 40 partners.

ECONOMY - IMPORTANT PROJECT OF COMMON EUROPEAN INTEREST (IPCEI)

In 2021, Austria started to implement the IPCEI European Battery Innovation (EuBatIn), with more than 40 participants from twelve EU member states. In total, triggering investments of up to 28 bn EUR ($32 bn US) dedicated to battery research and first industrial deployment. The IPCEI integrates the entire battery value chain from extraction of raw materials, design and manufacturing of battery cells and packs, and the recycling and disposal with a strong focus on sustainability. Six Austrian partners contribute with their expertise in order to establish a sustainable battery cell production in Europe.

HEVS, PHEVS, AND EVS ON THE ROAD

FLEET DISTRIBUTION AND NUMBER OF VEHICLES IN AUSTRIA

According to provisional figures, the total fleet of motor vehicles registered in Austria surpassed the second time in history the number of seven million. 7.21 million motor vehicles were registered as of 31 December 2021. That is an increase by 1.64% or 116,156 vehicles compared to 2020. Passenger vehicles, the most numerous type of vehicle (share: 71.2%), showed an increase by 0.8% to 5.13 million vehicles. Fleet numbers indicate a continuous trend toward advanced alternative propulsion systems, especially toward BEVs and HEVs (Figure 2).

The latter fleet numbers of 76,539 and 136,974, respectively, continue the positive trend of previous years, which follows an exponential trajectory. The number of vehicles driven by compressed natural gas (CNG) and liquefied petroleum gas (LPG), including bivalent ones, shows a stable, but very moderate fleet level of 5,787 vehicles (2020: 6,063). There is a slow decrease of bivalent vehicles to 3,132 (2020: 3,308; 2019: 3,474), while the CNG vehicles fleet stays stable with 2,654 (2020: 2,753; 2019: 2,602). With 55 (2020: 45) vehicles, the fuel cell electric vehicle (FCEV) fleet is still negligible.

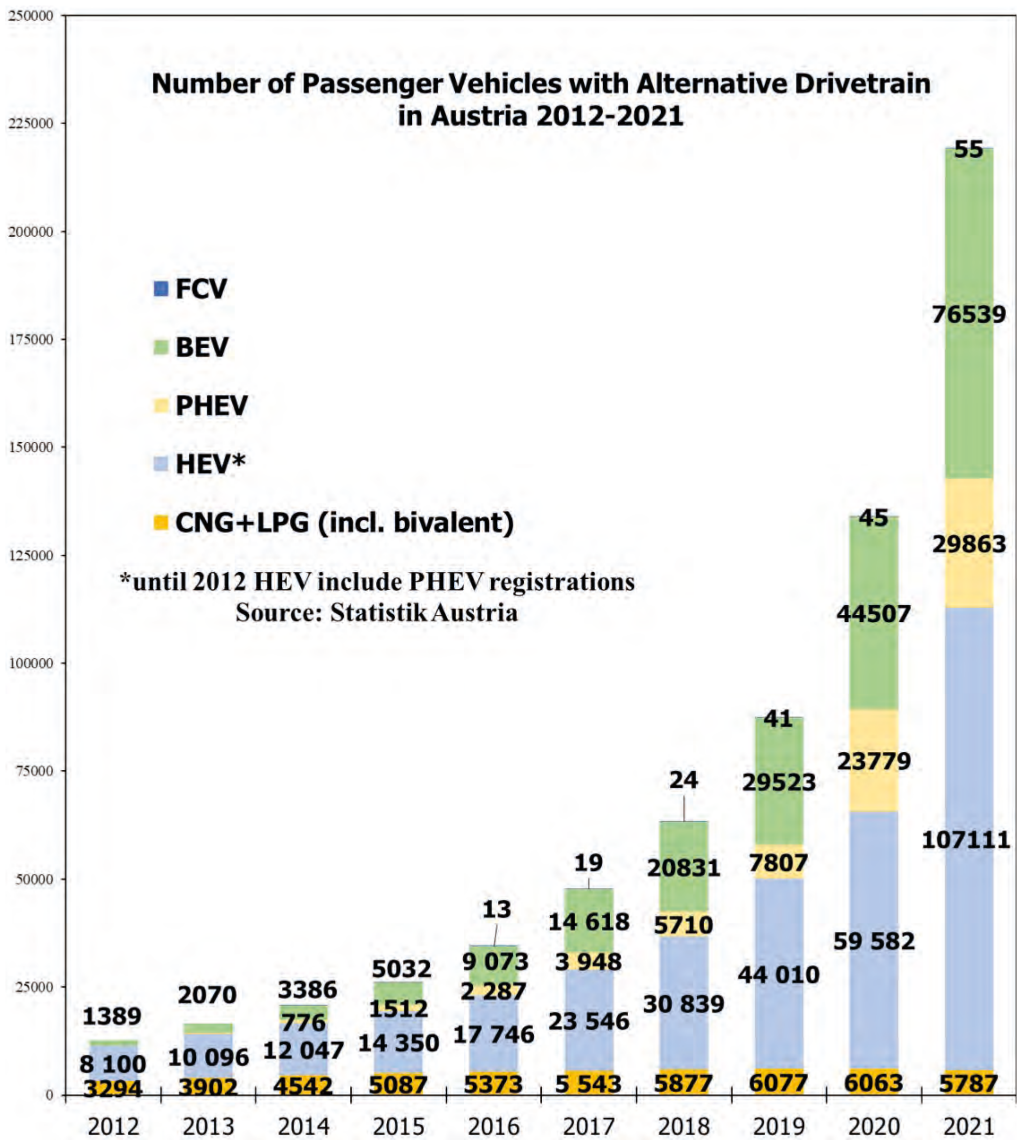


Figure 2: Trends for vehicles with alternative drivetrains in Austria, 2012–2021

Source: Statistik Austria

SHARE OF VEHICLE OWNERSHIP FOR BEVS DEVIATES FROM AVERAGE

In 2021, an average 66.5% of new passenger cars were registered to legal entities, companies and regional authorities, 33.5% to private vehicle owners. In relation to BEV registrations, the picture differs, as 83.5% of all new BEV car registrations can be assigned to legal entities, companies, and local authorities, while only 16.5% to private vehicle owners.

Average CO2 emission of passenger cars

The average CO2-emissions of newly registered passenger cars in 2021 amounted to 135 g/km based on the Worldwide Harmonised Light Vehicles Test Procedure (WLTP) test procedure (all-electric and hydrogen vehicles have not taken into account). The number drops to 116 g/km including electric and hydrogen vehicles. The average number for petrol-powered M1 vehicles is 139 g/km (2020: 143 g/km), and diesel-powered passenger vehicles show an average of 150 g/km (2020: 156 g/km).

Fleet Totals (as of December 31st 2021)

*Total including ICEVs

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike (2020 numbers)	n. a.	0	0	0	6,500,000
Electric moped (<50 kmph)	10,742	1		0	276,440
Auto-rickshaw	379	0	0	0	1,396
Motorcycle	3,233	6		0	595,677
Motorcycle with sidecar	n.a.	n.a.	n.a.	n.a.	n.a.
Motorized tricycle	23	3		0	104,610
Passenger vehicles	76,539	107,111	29,863	55	5,133,836
Buses and Minibuses	174	185		1	10,136
Light Commercial vehicles	5,627	307		0	493,387
Medium and Heavy Weight Trucks	44	5		0	54,646

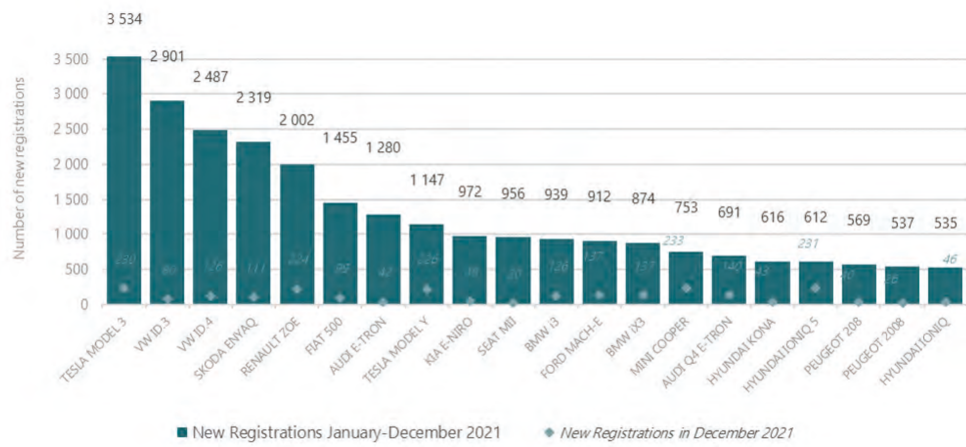
Total Sales 1st Jan 2021 to 31st Dec 2021

*Total including ICEVs

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike (2020 numbers)	203,515	0	0	0	496,434
Electric moped (<50 kmph)	2,461	0	0	0	12,396
Auto-rickshaw	169	0	0	0	192
Motorcycle	932	0	0	0	32,351
Motorcycle with sidecar	n. a.	n. a.	n. a.	n. a.	n. a.
Motorized tricycle	0	0	0	0	394
Passenger vehicles	33,366	41,970	14,626	14	239,803
Buses and Minibuses	11	62		0	887
Light Commercial vehicles	2,341	264		0	58,806
Medium and Heavy Weight Trucks	38	0	0	0	3,755

BEV M1 BRAND DISTRIBUTION

In the period from January to December 2021, the most popular model was the Tesla Model 3 with 3,534 units, followed by the VW ID.3 with 2,901 units and the VW ID.4 with 2,487 units. In relation to the overall market share, VW leads with 18%, followed by Tesla (14%) and Renault (7%).



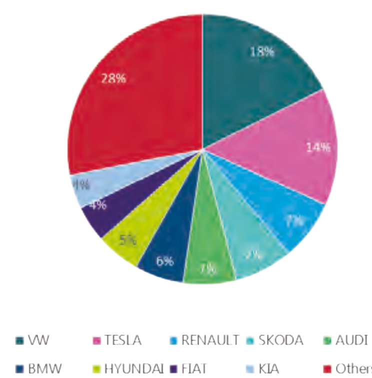


Figure 3: BEV M1 registrations by model (2021)

Source: Statistik Austria; Image courtesy of AustriaTech

CHARGING INFRASTRUCTURE OR EVSE

The number of publicly accessible charging points (EVSE) is rising continuously. In 2021, 8,994 normal power recharging points (with up to 22 kW and 1,674 high power recharging point above 22 kW according to the European Directive 2014/94/EU nomenclature) were operational.

PUBLICLY ACCESSIBLE CHARGING FACILITIES DIRECTORY[5]

The degree of diffusion and the availability of publicly accessible charging infrastructure are decisive factors influencing its user-friendliness, and thus success factors for the establishment of electromobility. In order to create a reliable reference for publicly accessible charging infrastructure, an official directory of all publicly accessible charging facilities for electric vehicles in Austria has been created and made available online. This directory contains information on the technical equipment, the charging possibilities, and the charging capacity.

The charging point directory is designed to inform about the availability of publicly accessible charging infrastructure, to promote competition between charging infrastructure operators, to strengthen the confidence of potential buyers of electric vehicles, and to counteract the fear of coverage. EVSEs with no publicly accessible chargers are not covered. Therefore, the numbers below do not include networks with restricted customer access, such as TESLA charging facilities, or limited charging possibilities, which are offered for free use as service of e.g., shopping malls or hotels.

* As of December 31st 2021

Type of Public EVSE	Number of Charging Points*	Number of Locations*
AC Level 1 Chargers (≤3.7 kW)	1,155	615
AC Level 2 Chargers (>3.7 kW, ≤22 kW)	7,915	3,904
AC Fast Chargers (43 kW)	415	369
DC Fast Chargers (≤50 kW)	630	399
Tesla Superchargers (DC >120kW - 250kW)	Not publicly accessible	Not publicly accessible
Ultrafast-High power chargers (DC >50 kW and ≤350 kW)	553	300
Inductive Chargers (EM charging)	n.a	n.a

EV DEMONSTRATION PROJECTS

ENERGY MODEL REGION[6]

As part of the "Energy Model Region" initiative, made-in-Austria energy technologies are developed and demonstrated in large-scale, real-world applications with international visibility. In the coming years, the Austrian Climate and Energy Fund (KLIEN) invests up to €120 million ($137 million US) in three Energy Model Regions. One such region -WIVA P&G - demonstrates the transition of the Austrian economy and energy production to an energy system based strongly on hydrogen. Particular emphasis is given toward the development of hydrogen transport applications, like in the HyTruck – Hydrogen Truck Austria project.[7] The WIVA P&G Energy Model Region forms part of the Mission Innovation Hydrogen Valley family.[8]

KLIMAAKTIV MOBIL PROGRAM

Austria's national action program for mobility management, called klimaaktiv mobil[9], supports the development and implementation of mobility projects and transport initiatives that aim to reduce CO2 emissions. Since 2004, 421,900 climate friendly mobility projects have received financial support. The klimaaktiv mobil website offers a map with details of each project. Total financial contribution amounted to €167.5 million ($191 million US) until the end of 2021.

R&I MOBILITY STRATEGY 2030

The R&I Mobility Strategy 2030[10] provides financial support for R&I projects and R&I activities on issues of sustainable passenger and freight transport within the context of the four mission areas Cities, Regions, Digitalisation, and Technology. The annual budget of funding is between €15 million and €20 million ($17 million and $23 million US). A project database is accessible via www.projekte.ffg.at

ZERO EMISSION MOBILITY & ZEM IMPLEMENTATION PROGRAM

Both programs, The Zero Emission Mobility (ZEM) & ZEM implementation[11] program, fund flagship projects for implementing the e-mobility initiative of the Austrian Federal Government. The programs focuses on zero emission mobility demonstration projects and their corresponding charging/refuelling infrastructure in transport with an obligatory implementation perspective. The calls are technology neutral, encompassing the three pillars, vehicle – infrastructure – user. Under the flagship program, 36 projects with 320 project partners and an overall funding of 68 million EUR ($78 million US) with a total investment of 217 million EUR ($247 million US) have been initiated.

EMOTION[12]– ZEM-DEMONSTRATION PROJECT EXAMPLE

Present-day electric two-wheelers in the power range between 1 and 11 kW are currently not designed for mass distribution and show weaknesses in the fields of efficiency, driving range and comfort.

The Emotion project "Electric Mobility in L-Category Vehicles for all generations" aims to eliminate these shortcomings by providing a modular and highly efficient architecture for electric two-wheelers. This significantly reduces manufacturing and maintenance costs. The vehicle development is focused on lightweight frame design, highly efficient electric powertrain, and charger components, removeable battery modules, and an innovative and user-centred designed human-machine interface including an eco-coaching algorithm.

Figure 4: Emotion L-Category Vehicle

Image courtesy of Numerica/ KTM

In order to demonstrate the synergetic potential of these solutions, an 8-month pilot phase is being carried out in both the urban and rural areas in and around Salzburg.

OUTLOOK

Austria's ambitious goal to become carbon neutral by 2040 asks for concerted activities in all sectors. Especially in the mobility sector, novel approaches are required. Therefore, Austria has launched a Mobility Master Plan, which lays out the path to climate neutrality in 2040 through identifying ways to avoid traffic by shifting traffic to public transport and active mobility, via increasing energy efficiency and through replacing fossil fuels with renewable energy sources. New solutions from research, technology, and innovation need to be brought swiftly to market for achieving the mobility-related climate targets.

For facilitating the transition towards a carbon neutral mobility system, the Austrian Automotive Transformation Platform (AATP)[13] will be established. Its core is formed by a group of experts covering the whole mobility community, thus including representatives from the vehicle and supplier industry, the charging infrastructure industry, the service sector, as well as clusters, stakeholders, research, and administration. The AATP will develop a catalogue of measures with recommendations for action to support the transition in the mobility industry.

The Alternative Fuels Infrastructure Regulation (AFIR) is being discussed at the moment, which will set out the future framework for the deployment of charging and refuelling infrastructure across the European Union. The document will include mandatory targets for member states, instead of today's indicative targets.

International co-operation and learning from each other's experiences is key for the swift transition toward electro mobility. The Technology Collaboration Programme is an international expert forum, where Austrian representatives benefit from their active participation. Austria is keen on continuing its previous activities, such as the LCA Task in the framework of the HEV TCP partners, and on opening new fields of co-operation through e.g., joining the AMT TCP.

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Belgium

ELECTRIC MOBILITY IN BELGIUM

Introduction

The automotive industry always played an essential role in the Belgian economy. High-quality cars, trucks, buses, and other vehicles are developed and/or produced in Belgium. The automotive sector has an annual turnover of about 16 billion € and counts more than 300 companies with more than 45.000 direct jobs.

The automotive and mobility industry in Belgium is in a transition towards an industry of clean, connected, and smart mobility. Especially the traditional car assembly was under severe pressure during the past decades. In recent years, two Belgian car manufacturing plants have made important investments for electric car manufacturing, as well as battery pack assembly. But also, in the automotive supplier's industry, there are successful companies and new start-ups. For future job creation, our industry must continue to make the right choices and has to remain very efficient and innovative. Within the automotive sector, it is not only about making and selling vehicles anymore. It is about offering a clean, comfortable, seamless, and affordable mobility service to the end customer.

The automotive and energy sector are both in a transition towards complete decarbonization, which is critical to reach the EU's 2030 climate objectives and the long-term strategy of achieving carbon neutrality by 2050. Electric mobility and batteries will play an important role in this transition. The transport and energy sector will become more and more interlinked, and this creates new business opportunities for companies in this new e-mobility value chain (batteries, vehicles, charging infrastructure, digital mobility applications, ICT, smart mobility, and energy services).

Passenger Cars

Today, Belgium still hosts two passenger car assembly plants: **Volvo Cars in Ghent** and **Audi in Brussels**. Both OEMs are active in the field of electric mobility and have their own battery assembly plants. Toyota Motor Europe has its European headquarter, logistics centres, and technical R&D centre with state-of-the-art Zaventem Proving Ground in Belgium.

Volvo Car Gent has been producing cars in Ghent since 1965. Today, it has about 6.500 employees. In 2020, the focus of the plant was mainly on the electrification of its models. Production of the Volvo XC40 Recharge, the first full electric model within the Volvo group, started in 2020. In March 2020, the battery assembly plant opened.

Figure 1: Battery assembly for electric vehicles at Volvo Cars' plant in Ghent, Belgium.

Source: Volvo Car Group

Volvo Car Gent announced to triple its production capacity for electric vehicles, with the ambition that in 2022 the share of electric vehicles will be 60% of the total production. In 2021, Volvo Car Gent started the production of Volvo C40 Recharge, which is the first Volvo designed as a full electric vehicle on the CMA-platform.

The site of **Audi Brussels,** established in 1949, is a key plant for electric mobility in the Audi Group. Since 2018, Audi produces the Audi e-tron, the brand's first all-electric SUV. For the production of the Audi e-tron, the Brussels site also has its own battery manufacturing facility. Today, Audi Brussels is also producing Audi e-tron Sportback in its CO2-neutral factory. Audi's Belgian subsidiary is the world's first certified CO2-neutral manufacturer in the premium segment. In a later phase, Audi Brussels will start to produce the Audi Q8 e-tron.

Suppliers

Belgium hosts about 300 suppliers to the automotive industry. A lot of the innovations in the automotive are taking place on the supplier's side. In Belgium we have renowned suppliers like e.g. **Umicore, Siemens, ABB, Melexis, PEC, Leclanché, DAF, Borit, Punch Metals, Solvay, 3M, JSR Micro, and Punch Powertrain.** Most of these companies are active in electric mobility.

Trucks

Volvo Europa Trucks is part of the Volvo Group and is the largest production facility of Volvo trucks. The Ghent site of Swedish truck builder Volvo Trucks is also going to assemble batteries for the company's electric models. Batteries will be built to supply all of Volvo Trucks' sites across Europe.

Volvo Trucks started manufacturing the Volvo FL Electric and Volvo FE Electric in 2019. Volvo Trucks announced that in 2021 hauliers in Europe will be able to order all-electric versions of Volvo's heavy-duty trucks. This means that Volvo Trucks will offer a complete heavy-duty range with electric drivelines for distribution, refuse, regional transport and urban construction operations. Volvo Trucks will be offering holistic solutions that include route planning, correctly specified vehicles, charging equipment, financing, and services.

In January 2021, the creation of a new business area was announced, Volvo Energy, with the purpose of strengthening the business flow of batteries over the life cycle. The new business area Volvo Energy will strengthen the Volvo Group's business flow of batteries over the life cycle, as well as the customer offer for charging infrastructure. At the same time, the environmental impact from electric and hybrid electric commercial vehicles and machines will be reduced by giving used batteries a second life in different applications.

MOL CY, founded in 1944, is producing heavy-duty vehicles for different applications: Waste Systems, Rail Equipment, Special Trucks, and Terminal Tractors. More and more research is going into ecological solutions like hybrid refuse collection vehicles and full-electric terminal tractors.

Electric Buses

Van Hool is an independent Belgian manufacturer of buses, coaches, and industrial vehicles. The company, founded in 1947, is established in Koningshooikt. The vast majority of its production goes to Europe and the United States. Van Hool has over 4,100 employees worldwide, of whom the largest share work at the production sites in Koningshooikt (Belgium) and Skopje (North Macedonia).

Van Hool has a long tradition related to fuel cell buses and was the coordinator of fuel cell electric bus European projects like “High VLO City” and “3Emotion”. Significant contracts have been signed in previous years to supply hydrogen buses and hydrogen-powered vehicles throughout the USA and Europe.

Related to electric buses, Van Hool announced in 2020 the launch of the CX45E, which is a fully electric powered coach for the North American market. The CX45E is being commercially launched by Van Hool’s North American exclusive distributor ABC Bus Companies Inc. Proterra, a leading American producer of battery technology for heavy duty vehicles, was selected by Van Hool to supply the E2 battery technology. The 100% electrically driven vehicle has a range of up to 500km (310 miles), depending on the climate conditions and the route’s topography. A pilot program road test conducted by MTRWestern and ABC demonstrated it was possible to conduct a travel of 1.700 miles in 4 days with a Van Hool CX45E (Source: MTRWestern and ABC Travel 1700 miles in Van Hool CX45E | Busworld North America).

VDL Bus Roeselare, part of VDL Bus & Coach bv, produces public transport buses and coaches in the city of Roeselare. VDL Bus Roeselare plays a significant role in the development and production of the full electric public transport bus portfolio within the VDL Group. VDL Bus Roeselare has about 700 employees, and turnover of VDL Bus Roeselare doubled in 2019.

VDL Bus & Coach is one of the front runners in electric mobility, looking at the number of electric buses produced and in use in Europe. Since the introduction of the first Citea SLF-120 Electric in Geneva in 2013, VDL Bus & Coach has focused strongly on electric mobility. More than 800 electric buses VDL Citeas are in operation in 65 projects in more than 55 cities all over Europe, and the magic limit of 100 million electric kilometres has been reached.

In 2021, VDL Bus & Coach presented the new generation of electric Citeas. Deliveries are ongoing like e.g., in the city of Oberhausen (Germany), where local public transport operator Stoag welcomed the first batch of 15 new-generation electric Citea by VDL (Source: Fifteen new generation Citea by VDL for operator Stoag, in Oberhausen (sustainable-bus.com)).

DE LIJN - THE FLEMISH PUBLIC TRANSPORT COMPANY

The **Electric Bus Systems (EBS) program** within De Lijn implements the mission, vision, and objectives of the transport company with regard to the phased introduction of emission-free driving in Flanders via the greening and modernisation of the fleet. The program fits in with the introduction of the Basic Accessibility decree and the 2019-2024 coalition agreement of the Flemish government. It implements the objectives of optimal emission-free driving in urban areas by 2025 and full zero-emission service in the whole of Flanders by 2035.

The EBS program is based on three pillars:

- The phased acquisition and introduction of e-buses, with their charging infrastructure, conversion of depots, ICT infrastructure, and the integration of this ecosystem into the entire De Lijn organisation.

- The expansion, optimisation, and rearrangement of the existing fleet of e-hybrid buses of De Lijn, complementary to the introduction of e-buses, as a transition to achieve the 2025 and 2035 targets.

- Facilitating emission-free public transport in the network of subcontractors, who account for about half of the bus kilometres and vehicle task assignments (VTAs) of De Lijn and therefore have a necessary contribution to make to the challenge.

Figure 2: First order of 60 e-buses in total (12m) from Van Hool and VDL

Source: De Lijn

Based on the current state of affairs, De Lijn chooses:

- E-buses: electric battery buses with sufficient autonomy for a full bus run during the day and that are charged at converted depots overnight (and in between day runs). These buses are introduced into the fleet via phased tenders. The first order of 60 standard (12 m) e-buses with an autonomy of more than 400 km on a single charge was announced in December 2021: 36 e-buses have been ordered from Van Hool and 24 e-buses from VDL.

- E-hybrid buses: the purchase of e-hybrids and conversion of existing and ordered hybrids in order to remove the most polluting buses from the fleet as quickly as possible. This pillar fits within the fleet life cycle of 14 years (15 years for e-buses) and CAPEX optimisation. Together with the e-buses, e-hybrids will enable De Lijn to achieve the 2035 target for its own fleet. The upgrade of 280 existing standard and articulated hybrids to e-hybrids, and an order of 44 new articulated e-hybrids, was announced in July 2021. They have a range of up to 100 km on a single charge, and can recharge their battery packs while driving on their EUR6 diesel engine.

- Engaging subcontractors within the framework of existing and forthcoming contracts.

In this way, De Lijn plans to have ordered and/or have in service around 1.500 e-buses and e-hybrids, and related infrastructure by 2026, both in its own fleet and via subcontractors.

The result of this exercise is that by 2025, we can reduce particle and nitrogen oxide emissions by 75%; by 2026 by 89%.

The total investment to reach the 2035 zero emission target for both the entire fleet and its infrastructure and the De Lijn organisation amounts to between € 3.9 and € 5.2 billion, depending on the conversion work to be carried out at the depots. Compared to a "do nothing" diesel scenario, in which no e-buses and related infrastructure are introduced, an average of the lowest and highest scenario would mean an additional financial effort of € 1.75 billion.

Electric Motorcycles

Trevor Motorcycles teamed up with Maison Saroléa for the R&D of their first motorcycles based upon John McInnis's design. This resulted in the electric urban flat tracker; the Trevor DTRe Stella. This premium model will be hand built at Maison Saroléa in Belgium. Because of the relationship Trevor Motorcycles has with Saroléa Performance Technology, they will always work with C-battery for their battery packs, also for future models.

Figure 3: Trevor DTRe Stella Electric Motorcycle

Source: Trevor Motorcycles

At this very moment, Trevor Motorcycles is ending the EU type approval of the DTRe Stella at IDIADA in Spain. So, the first bikes that leave the production line in Spring 2022 will be street legal and ready for the urban jungle. At this moment, only 10% of all Trevor are sold to racers and dirt tracks, and 90% of the sales is going to people that want to use the Trevor as a cool urban motorcycle. The big 19" wheels with fat tyres in combination with the wide handlebars and the low weight of less than a 100kg makes the Trevor so usable downtown.

Logistics

Flanders also plays an important role in automotive logistics. Thanks to its well-equipped ports with a good central location in Europe, Flanders is becoming a key player for electric vehicles logistics. The Port of Zeebrugge, already the world's largest port for the shipment of light vehicles, has also become a key hub for e-cars.

Figure 4: ICO Zeebrugge – more than 300 charging points installed.

Source: ICO and CKS

Thanks to International Car Operators (**ICO**), a Japanese leader in car transhipment, the port is fully equipped to import electric cars into Europe and created a green terminal. To charge the e-cars arriving at the port, a large number of electrical loading stations are installed, and to provide the necessary power, solar panels and an onshore wind farm have been installed.

NATIONAL POLICY FRAMEWORK

In response to the **Alternative Fuels Infrastructure Directive (AFID)** (Directive 2014/94/EU) of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure, Belgium has developed a policy framework regarding alternative transport fuels/infrastructure.

Given the complex institutional context in Belgium (both regional and federal entities are directly involved) and the various involved policy areas, such as economy, mobility, energy, environment, finances, etc., an interdepartmental transversal government working group (Energy-Transport) was created.

The Federal Public Service of Economy and the Federal Public Service of Mobility & Transport (federal government of Belgium) coordinated the national concertation and development of the Belgian policy framework. However, the regions of Belgium (i.e. Flemish region, Walloon region & Brussels-Capital region) are competent for most aspects of Directive 2014/94.

Flemish Policy Framework

The Flemish policy framework regarding alternative fuels infrastructure for transport in response to Directive 2014/94/EU started with the Flemish **CPT-Action Plan 2020** that was followed by the **CPT-Vision 2030.**

Extra concept notes related to **"Approach roll-out charging infrastructure 2021-2025"** and **"Sustainable city logistics"** have been added as integral parts of the CPT-Vision 2030.

The ambitions in the CPT-Vision 2030, as included in the Flemish Energy and Climate Plan 2021-2030, have been scaled-up with 30.000 extra charging points by 2025 (locations will be mainly demand-driven). For passenger cars, the ambition is to reach 50% zero-emission passenger cars in new sales by 2030, and to study the date for a complete phasing out of the sale or registration of new internal combustion engine

(ICE) passenger cars. On the longer term, the ambition is to go to a full zero-emission fleet for 2-wheelers, passenger cars, vans, and city buses. Only for heavy-duty trucks will multiple options be studied.

The ambition in the CPT-Action Plan 2020 was to reach 100.000 (PH)EVs in Flanders in 2020, and this target was almost reached (around 91.000). At the end of 2020, there were around 5.000 public charging points spread over Flanders. Since 2017, the roll-out of quick-chargers started on the high-ways (partly via BENEFIC CEF funding). The whole charging infrastructure roll-out was complemented by projects stimulating home charging and work-place charging. The balance between number of charging points versus number of EVs on the road needs to be monitored constantly.

More than 60 CPT-projects have been executed, studying electrification of taxis, buses, company car fleets, car sharing, LEVs, and the integration of charging infrastructure in the grid (smart charging). These projects studied the state-of-the-art and benefits/barriers for the roll-out of certain technologies, which also gave input for future policy making.

A lot of focus went to passenger cars in the first CPT-projects. However, as preparation to the CPT-Vision 2030, also specific studies for Light Electric Vehicles (LEVs) and electric buses (see chapter De Lijn) have been executed. Also, a roadmap on reduction of emissions of freight transport has been developed.

The ambitions in the CPT-Vision 2030 are to develop policies that support and accelerate the transition to zero-emission transport. This requires a multi-disciplinary approach, including aspects like the roll-out of new technologies, but also aspects like economic benefits, social inclusion, and end user satisfaction. The ecological benefits should contribute to the ambitions in the **“Flemish Energy and Climate Plan 2021-2030”** for the reduction of CO2 emissions. Also, air quality is an important aspect, and zero-emission transport can contribute to the “Air Policy Plan 2030”. Focus will be on densely populated city areas. The ambition is to have by 2025 in inner cities a zero-emission public transport, and also the impact of freight transport should be reduced. The use of low-emission-zones (or even zero-emission-zones) will be continued to stimulate the zero-emission mobility in inner cities.

Table 1: Targets in new sales per type of vehicle

Source: CPT-Vision 2030

		2025	2030
Passenger Cars	Zero-emission	20%	50%
	PHEV	10%	20%
	CNG	10%	10%
Mopeds	Zero-emission	100%	100%
Motorcycles	Zero-emission	20%	50%
Vans	Zero-emission	11%	30%
	PHEV	7%	14%
	CNG	10%	20%
Trucks	Zero-emission	0%	5%
	LNG/CNG	5%	15%
Buses (Public Transport)	Zero-emission	50%	100%
	PHEV	20%	0%
Buses (Other)	Zero-emission	5%	10%
	PHEV	10%	20%
	CNG	10%	20%

For passenger cars, policy measures will stimulate only the use of BEV passenger cars, with the ambition to have 100% share in new sales by 2035.

The new tax law on the greening of mobility in Belgium has the ambition that all new company cars should be zero-emission cars by 2026. In general, the reform consists of three major elements. First of all, the tax treatment of company cars will evolve, and as of 2026, costs related to company cars will only be eligible for tax deductions in case of a zero-emission company car. Next to that, the solidarity contribution will also undergo changes in order to stimulate the usage of zero-emission cars. Furthermore, tax incentives will be foreseen to deploy electrical charging infrastructure in Belgium.

Tax incentives for electrical charging infrastructure

As the Belgian government has decided to entirely electrify the Belgian company car fleet, this will lead to an extensive increase in the need for infrastructure to charge electric cars. As a result, the new tax law also foresees in two tax incentives to encourage companies and individuals to install charging stations (Source: https://www.ey.com/en_be/tax/tax-alerts/new-tax-law-on-the-greening-of-mobility)

INCREASED COST DEDUCTION FOR THE INSTALLATION OF PUBLICLY ACCESSIBLE CHARGING STATIONS

In order to encourage companies to invest in charging infrastructure for electrical cars, the Belgian government announced an increased cost deduction for the depreciations of newly installed publicly accessible charging stations.

The increased cost deduction will be applicable on eligible investments made from 01/09/2021 until 31/08/2024. As the Belgian government wants to encourage short-term investments, the deduction rate will decrease over time.

The following rates apply:
- Eligible investments made between 01/09/2021 and 31/12/2022: 200%
- Eligible investments made between 01/01/2023 and 31/08/2024: 150%
- As of 01/09/2024: 100%

In order to benefit from the increased cost deduction, the charging station **should be publicly accessible**, which implies that the charging infrastructure should at least be accessible to third parties (during either the normal opening hours or during the normal closing hours of the company) and public, in the sense that users can verify both the location and availability of the charging station. Furthermore, companies have the obligation to report the available charging stations to the FPS Finance so that the available charging stations can be mapped.

Another condition to benefit from the increased cost deduction lies in the fact that the installed charging station **should be an intelligent charging station**. This means that the charging time and charging capacity can be linked with an energy management system (however only necessary/applicable as from income year 2023). Investments in non-intelligent charging stations are thus not eligible for the increased cost deduction.

TAX REDUCTION FOR THE INSTALLATION OF A HOME CHARGING STATION

In principle, electric cars can be charged through a charging cable via a standard electrical outlet. However, studies have shown that this charging method entails serious risks of fire safety and overloading of the electricity grid. In order to reduce these risks, the Belgian government wants to encourage individuals to invest in a home charging station. In addition, a home charging station does not only reduce the risks, but the charging speed is also up till 10 times higher compared to charging via a standard electrical outlet.

As a result, the new law foresees a tax reduction for investments made by individuals in a home charging station. In this way, the Belgian government aims to encourage people to charge their electric car at home by reducing the total cost of the installation of a home charging station.

The tax reduction shall be granted for expenses paid by a taxpayer **for the purchase and placement of a charging station** at the address where he or she has established his/her **place of residence** on January 1st of the tax year in which the tax reduction is claimed. As a result, it is not necessary that taxpayers are already residing in the property where the home charging station is being installed at the moment of the installation or the payment of the home charging station. Furthermore, the tax reduction can not only be claimed by the owner of an immovable property, but **also tenants who invest in a home charging station can enjoy the tax reduction too.**

Similar to the above-described increased cost deduction for the installation of publicly accessible charging stations, the tax reduction is **only applicable for investments in intelligent charging stations**. However, the new law imposes an additional condition to benefit from the tax reduction: the home charging station may only **use renewable energy.** Furthermore, taxpayers who want to claim the tax reduction have the obligation to have the home charging station **installed by a professional.** Home charging stations installed by the taxpayer themselves are not eligible for the tax reduction.

The following expenses are eligible for the tax reduction:
- The purchase price and installation cost of the home charging station;
- Expenses to increase the electricity installation from one to three phases;
- Expenses for the mandatory inspection of the installation;

The tax reduction can be claimed on a **maximum amount of 1500 EUR per home charging installation and per taxpayer.** The tax reduction is limited to expenses made between 01/09/2021 and 31/08/2024. **A taxpayer can only benefit one time from the tax reduction.** If a taxpayer made expenses during two different calendar years, he or she can only claim the tax reduction for the costs incurred in one of these two years.

The applicable tax reduction rate will decrease in time:
- Eligible expenses made between 01/09/2021 and 31/12/2022: 45%
- Eligible expenses made between 01/01/2023 and 31/12/2023: 30%
- Eligible expenses made between 01/01/2024 and 31/08/2024: 15%.

HEVS, PHEVS, AND BEVS ON THE ROAD

Statistics on the number of PHEVs and BEVs on the road in Belgium can be found on the European Alternative Fuels Observatory. End of 2020, there were 33.703 BEVs and 74.988 PHEVs on Belgian roads (Statistics Belgium: https://www.eafo.eu/countries/belgium/1724/summary)

CHARGING INFRASTRUCTURE OR EVSE

Introduction

Within the **National Policy Framework "Alternative Fuels Infrastructure"**, extra policy measures have been taken to stimulate the market for charging infrastructure in Flanders, Walloon Region, and Brussels Capital Region.

Getting an up-to-date overview on all charging points available in a country is not an easy task, because this information is spread out over the different market players. But the charging infrastructure market is starting to organize themselves in a more structured way, and most charging infrastructure operators are now joined in a dedicated working group at **EV Belgium**.

Drivers of electric vehicle should have easy access to detailed real-time information of the (semi-) public charging infrastructure: location, ways of access, availability, prices, etc. Today, this information is still scattered over different databases/websites/apps, and not always up-to-date and certainly not available in an easy and standardised way. Improvements are needed to achieve a more user-friendly access to detailed real-time charging infrastructure information. Therefore, Belgium initiated **Task 39 "Interoperability of e-mobility services"** together with Canada, France, Spain, Switzerland, The Netherlands, and USA. Task39 brings together experts from member countries to share information and best practices to improve the interoperability and accessibility of charging services. For more details, you can read the chapter dedicated to Task39.

Programme Support Action (PSA) on ID issuing and data collection for alternative fuels (IDACS) (2019-2021)

The PSA IDACS has been set-up by the European Commission to support Member States in setting up data collecting for alternative fuels and make the data available through the National Access Points, and to develop an effective, EU-wide coordination mechanism to assign unique identification codes to CPOs and EMSPs. The PSA had a duration of three years (2019-2021) and its Consortium consisted of 15 Member States: Austria, Belgium, Czech Republic, Croatia, France, Germany, Greece, Hungary, Lithuania, Luxembourg, The Netherlands, Poland, Portugal, Slovenia, and Spain.

The Consortium developed a format for the establishment of the first 5-digits of the e-mobility IDs for CPOs and EMSPs, and an EU-wide/coordinated approach regarding the remaining digits of the e-mobility IDs. Each of the Consortium-members has to establish an **ID registration organisation (IDROs)** at national level responsible for issuing and managing e-mobility IDs within each of the participating Member States. And a common **ID Registration Repository (IDRR)** needs to be established for the exchange between national IDROs.

Furthermore, the Consortium mandatorily has to collect data related to alternative fuels infrastructure, namely electric charging points and hydrogen refuelling stations (HRS). Other alternative fuels, such as CNG, LNG, LPG and highly-blended biofuels, are optional. The data needs to be made available through the **National Access Points**.

EUROPE E-MOBILITY ID REGISTRATION REPOSITORY (IDRR)

https://benelux-idro.eu/en/more-about/id-registration-repository-idrr

The Europe E-mobility ID Registration Repository (IDRR) is hosted by the **IDRO Benelux** on behalf of all European ID Registration Organizations (IDRO). The IDRR and its website have been introduced by the Consortium of the Programme Support Action IDACS in 2021.

IDRO

The IDROs need to maintain the ID registration for Charge Point Operators (CPOs) and Mobility Service Providers (MSPs) with a unique ID for each organisation. These IDs issued by the IDROs are used to identify charge contracts and charge stations (possibly also charge pools). The use of the unique IDs supports the cross-border use of charge stations by EV drivers, as it enables domestic and foreign ad hoc payments.

IDRR

The national IDROs collaborate at European level via the ID Registration Repository (IDRR). The IDRR provides relevant information on IDs, access to national ID registers and ID requests. It offers support to national IDROs with their activities, and Member States who do not yet have their IDRO. Furthermore, the IDRR also ensures long-term sustainable ID management.

IDACS is an abbreviation for ‘ID issuing and data collection for alternative fuels’ and aimed to support Member States in setting up data collecting for alternative fuels and make the data available through the National Access Points, and to develop an effective, EU-wide coordination mechanism to assign unique identification codes to CPOs and MSPs.

Statistics on Charging Infrastructure in Flanders

The ambition for 2020 was to have 7,400 publicly accessible charging points in Flanders. A new ambition has been announced to install 30,000 extra charging points by 2025. The Flemish Government has foreseen a budget of 30 m€ and approved a concept note for the roll-out of charging infrastructure for the period 2021-2025.

At the end of 2021, almost 5,800 public charging points are available in Flanders, of which about 200 fast chargers. Fast chargers can deliver a power of more than 22 kW (mostly 50 kW) and 92 of them are ultrafast chargers delivering a power of more than 150 kW. At the end of 2021, there were around 650 public charging points in Brussels and 475 public charging points in the Walloon region.

Part of the initial ambition was foreseen to be realised via the obligation of the Distribution Grid Operators (DGOs) to install 5,000 publicly accessible charging points through public procurement in 2020. Some cities followed their own course and have launched their own tenders. In order to differentiate between private and (semi) public charging infrastructure, a definition of publicly accessible charging points (24/7 accessibility) was integrated in the Energy Decree of the Flemish Government. The charging points are distributed over the more than 300 municipalities in Flanders. Local governments are responsible for the installation of the parking spot and parking policies (e.g. enforcement). The charging points should enable EV drivers to conveniently charge in Flanders.

In 2022, a new portal will be launched by the Department of Mobility (MOW) so that EV drivers can order a public charging station in their area if certain conditions are fulfilled ("Paal volgt Wagen"). In cities like Gent and Antwerp, citizens can request a public charging station via a dedicated website (example: https://www.antwerpenlaadt.be/en/).

The number of fast and ultrafast chargers has been rising as a result of European projects like Fast-E, Ultra-E, Mega-E, and BENEFIC, among others. **BENEFIC** (BrussEls NEtherlands Flanders Implementation of Clean power for transport) is an innovative cross-border project for the development of charging and refuelling infrastructure for alternative fuels for transport initiated by the Flemish Government in partnership with the Brussels Capital Region and the Netherlands. BENEFIC is funded by the Connecting Europe Facility (CEF) programme of the European Union (www.benefic.eu). Through 3 open calls for proposals in period 2018-2021, the partners selected 57 infrastructure projects for (ultra)(fast)chargers for electric vehicles, electric taxis and electric buses, CNG and LNG infrastructure, hydrogen refuelling infrastructure and onshore electricity supply facilities for inland navigation. The projects must be realised before September 2022.

CPT project call 2021 focussed on (semi-) public charging infrastructure on private domains like parking near shops, schools, companies. Conditions were that charging points need to be publicly accessible at least 10 hours per 24 hours. All EV drivers should get access at market conform conditions, and also "ad-hoc charging" is a must. Charging points should also make use of green electricity only. In total, 210 projects have been approved for a total subsidy of 8.2 million €, resulting in about 5.800 normal charging points, 130 fast chargers and 320 ultrafast chargers. Project execution is foreseen between 11/2021 and 11/2023.

An overview of all publicly accessible charging points is available on the clean vehicles' website (www.milieuvriendelijkevoertuigen.be/laden).

EV DEMONSTRATION PROJECTS

Shared Mobility in Flanders

Shared mobility is an important "piece-of-the-puzzle" towards a more ecological, economic, and social mobility offer fitting the needs of a very diverse group of users. Every user is unique and has different mobility needs. Therefore, a mix of transport modes will be needed, from public to individual transport and from privately owned vehicles to salary cars and shared mobility solutions. The trend towards the use of zero-emission and autonomous vehicles is also unstoppable. Shared mobility is getting more popular in Flanders. The number of cities and the number of companies offering shared mobility solutions is constantly growing.

Green Deal Shared Mobility (2017-2021): inspired by the Dutch Green Deal on car-sharing, Autodelen.net, The Shift, The New Drive and Mpact took the initiative to launch a Green Deal Shared Mobility with the Flemish Government. The aim of the Green Deal was to accelerate the growth of shared mobility (car-sharing, carpooling, and bike-sharing), in Flanders. The Green Deal was signed by more than 100 organisations willing to undertake actions and to remove barriers to provide alternatives to car ownership. One of the thematic working groups was "electric shared mobility".

Autodelen.net is a non-profit organization stimulating and promoting shared mobility in Flanders since 2003. Bringing stakeholders together and inform them about the benefits and the available market offers is a key activity. The platform is also involved in policy and research activities. An overview of the car sharing operators active today in Flanders can be found on: https://www.autodelen.net/nl/aanbod/. Some platforms are peer-to-peer car sharing schemes (or personal vehicle sharing) while others are operated by car sharing companies. Some platforms are roundtrip-based, while others are free-floating.

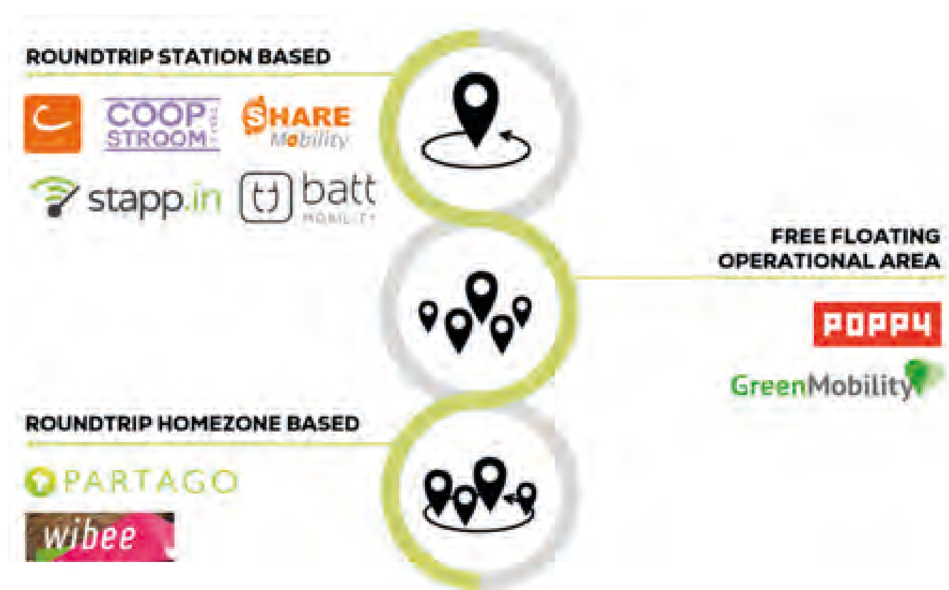

Figure 5: Car-sharing providers with own fleet in Belgium January 2021

Source: Autodelen.net

Autodelen.net published the latest statistics on car-sharing in Belgium (status January 2021), showing the huge potential of car-sharing. The number of users in Belgium went from 30.000 in 2017 to 150.000 in 2021, so an increase of factor 5! The car-sharing fleet contains almost 4.000 cars in total in Belgium, of which 642 electric cars. (16% of the total fleet).

Reuse and Recycling of Li-ion batteries

Flanders is also preparing itself to be able to re-use and recycle the batteries, which are end-of-life. Companies like Febelauto, BEBAT, Watt4Ever, ReVolta, Out of Use, are active in setting up the re-use and recycling process chain.

With **Umicore**, Flanders also has the expertise in house for the final recycling and extraction of valuable battery materials. As a materials technology and recycling group, Umicore is uniquely positioned in clean mobility materials, having focused its products and services on technologies that address the key global challenges of clean air (automotive catalysts), electrified transport (rechargeable battery materials) and resource scarcity (recycling). Umicore's innovation pipeline spans the next 20 years and beyond, aiming for higher energy density and longer driving range in electrified vehicles. Umicore and Volkswagen AG have announced at the end of 2021 that they plan to establish a joint venture (JV) focused on developing precursor and cathode material for electric vehicle (EV) battery cell production in Europe. Umicore and Volkswagen will also collaborate on the sustainable and responsible sourcing of raw materials. Both parties aim to include elements of refining and battery recycling into the scope of the partnership at a later stage.

WATT4EVER - REUSE IS THE NEW RECYCLING

Watt4Ever (www.watt4ever.be) specialises in transforming electric car batteries into high-quality circular energy storage systems. The company has 15 employees today and was founded in June 2020 by the following partners: ReVolta, Febelauto, Shence Management, Eco Lithium and Out of Use.

The company became a one-stop-shop for used EV batteries in Belgium. Watt4Ever builds new, green, and high added-value industrial storage systems coming from used electric vehicle batteries. The CO2 impact of a Watt4Ever battery is 80% lower than when using a new battery. In this way, the company helps to reduce the carbon footprint of electric vehicles, because after a life of about ten years in a car, the battery modules can serve another ten years in a Watt4Ever energy storage system.

Figure 6: The energy repository of the future: a recycled car battery

Source: Watt4Ever

The unique aspect of the Watt4Ever approach is that it manages the entire process, from the collection of discarded electric vehicle batteries to a circular battery installed at the customer's site, including optimisation of its energy production and use. This completely integrated approach is unique in Europe, and Watt4Ever won the ARN innovation award 2021.

RELIVE PROJECT "RECYCLING AND REMANUFACTURING OF LI-ION BATTERIES FROM END-OF-LIFE ELECTRIC VEHICLES"

The federation for the technology industry, Agoria, started a study called "LIFEBAT", with the goal to map out the opportunities and challenges for the companies in the Flemish Region in the complete value chain of the Lithium-ion battery. In 2019, the LIFEBAT study reported some concrete recommendations regarding actions and initiatives that are needed from the industry, from the government and from knowledge centres in order to strengthen the position of the Flemish Region in the complete Lithium-ion battery value chain.

LIFEBAT led to a follow-up project called Re2LiVe (https://re2live.be/) which is focussing on the collection, logistics, dismantling, remanufacturing, reuse and recycling of end of life Li-ion batteries from electric vehicles. In the framework of the Re2LiVe research project, VIL together with Sirris, VITO, and VUB, and with the support of SIM, Flux50 and Agoria, are investigating how Flemish companies can seize the opportunities in the growing market of used lithium-ion batteries from hybrid and electric vehicles. The recycling of lithium-ion batteries poses a number of challenges, but also offers opportunities for Flemish industry and logistics.

IPCEI for 'European Battery Innovation'

In January 2021, the European Commission approved a second project under EU state aid rules to support research and innovation in the battery value chain. The project, called 'European Battery Innovation', counts as an important project of common European interest, an IPCEI in short. It was prepared and notified jointly by Austria, Belgium, Croatia, Finland, France, Germany, Greece, Italy, Poland, Slovakia, Spain, and Sweden. The twelve Member States will provide funding of up to 2.9 billion euros over the next few years, to be complemented by private investment of nine billion euros. The IPCEI project will involve 42 companies. The EU Commission said that the 42 companies would work closely together in nearly 300 planned collaborations and with more than 150 external partners, such as universities, research institutes and SMEs across Europe. The overall project is expected to be completed by 2028, but each sub-project will follow its own timetables.

In December 2019, a first IPCEI on batteries was approved by the European Commission, in which seven member states (Belgium, Finland, France, Germany, Italy, Poland and Sweden) would provide up to approximately €3.2 billion in funding, and which is expected to unlock an additional €5 billion in private investments in a European battery value chain.

Belgian companies involved in IPCEI projects:

- First IPCEI on batteries: Umicore, Solvay and Nanocyl.
- Second IPCEI on batteries: Hydrometal and Prayon.

First, in approving this IPCEI with an unprecedented total value of 12 billion euros, Europe is raising its game in ground-breaking research and innovation.

The IPCEI battery projects will help revolutionize the battery market in Europe by focusing on beyond-state-of-the-art lithium-ion batteries, as well as on next-generation post-lithium-ion battery technologies. It will also foster new manufacturing processes with higher energy efficiency and lower carbon footprint across the entire value chain. It is expected that the IPCEI battery projects will lead to some 30 pilot lines and will help to create more than 18-thousand new jobs across the Member States.

Canada

MAJOR DEVELOPMENTS IN 2021

National Developments

The transportation sector accounts for one-quarter of Canada's greenhouse gas (GHG) emissions. Accelerating the transition to zero-emission vehicles (ZEVs) is therefore critical to meeting Canada's climate targets and achieving net-zero by 2050. Almost half of Canada's transportation emissions comes from cars and light trucks. The Government is supporting the transition to ZEVs through a range of measures, including investments and regulations for both light and heavy-duty vehicles. Canada is investing in re-tooling our manufacturing sector, consumer rebates, charging and fueling infrastructure, research development and demonstration (RD&D), as well as tax incentives to spur the deployment of ZEVs in Canada.

ZERO-EMISSION VEHICLE SALES TARGET

In June 2021, the Government of Canada announced it is setting a mandatory target for all new light-duty cars and passenger trucks sales to be zero-emission by 2035, accelerating Canada's previous goal of 100% sales by 2040. To ensure Canada reaches this goal and to provide certainty about the pathway to get there, the Government of Canada will pursue a combination of investments and regulations to help Canadians and industry transition to achieve the target.

In December 2021, the Government of Canada launched consultations on its commitment to require all new cars sold be 100% zero-emission by 2035, with an interim target of at least 50% by 2030.

Also in December 2021, Environment and Climate Change released a discussion document on heavy-duty vehicles and engines in Canada and the transition to a zero-emission future. This supports the Government's commitment, requiring 100% of selected categories of medium-duty and heavy-duty vehicles to be zero emission by 2040.

ZERO- EMISSION TRANSIT FUND

In August 2021, the Government of Canada launched a $2.16 billion USD ($2.75 billion CAD) Zero Emission Transit Fund - a five year national program to help communities invest in zero emission public transit and school transportation options. This includes switching to cleaner electrical power and supporting the purchase of zero emission public transit and school buses and associated infrastructure.

The Zero Emission Transit Fund supports the federal government's commitment to help purchase 5,000 zero emission buses over the next five years. This investment is being made in coordination with the Canada Infrastructure Bank's commitment to invest $1.2 billion USD ($1.5 billion CAD) in zero emission buses as part of its three-year Growth Plan.

STRATEGIC INNOVATION FUND – NET ZERO ACCELERATOR

The Government of Canada's Strategic Innovation Fund (SIF) supports large-scale, transformative, and collaborative projects that help position Canada to prosper in the global knowledge-based economy and promote the long-term competitiveness of Canadian industries, clean growth, and the advancement of Canada's strategic technological advantage.

As a key initiative under the SIF, the Net Zero Accelerator (NZA) was first launched in December 2020 as part of the Government of Canada's Strengthened Climate Plan, and was originally allocated $2.36 billion USD over five years. As part of the federal government's 2021 Budget, the NZA received an additional $3.94 billion USD in support of projects that will enable Canada to reduce its domestic GHG emissions.

The NZA initiative works to rapidly expedite decarbonisation projects with large emitters, scale-up clean technology and accelerate Canada's industrial transformation across all sectors, including the automotive sector, as well as establish a battery innovation and industrial ecosystem.

INVESTMENT INTO THE AUTOMOTIVE SECTOR TOWARD LOW AND ZERO EMISSION VEHICLE PRODUCTION

Canada's automotive sector has seen significant investments in low and ZEV manufacturing since 2020 from many of its established automakers and suppliers. Through SIF, the Government of Canada has funded projects that will further enhance the sector's pivot to ZEV production, including:

- $11.8M USD investment for Volvo Group Canada to modernize their public transit buses, optimize their electrification, and build other types of all-electric and battery powered buses.

- ~$39.3M USD investment for Lion Electric as part of an overall project of $145M USD to establish a highly automated battery-pack assembly plant for the all-electric truck and bus manufacturer.

Provincial and Territorial Developments

BRITISH COLUMBIA

In fall 2021, the Government of British Columbia released its CleanBC Roadmap to 2030, accelerating measures to help B.C. achieve emission reduction targets for 2030 and reach net-zero by 2050. As part of BC's Roadmap to 2030, some of the elements to accelerate the move to lower-carbon transportation include requiring 26% of all new, light-duty vehicles (LDVs) sold to be ZEVs by 2026, rising to 90% by 2030, and 100% by 2035. Targets will be developed for medium- and heavy-duty vehicles. As part of the Roadmap to 2030, the province has set a target of 10,000 public EV charging stations by 2030.

NEW BRUNSWICK

In July 2021, the Government of New Brunswick announced new incentives for the purchase of a qualifying new and used Plug in EVs. Incentives are also available for qualifying network capable residential EV chargers. The 3-year incentive program will help New Brunswick meet its target of 20,000 EVs by 2030.

NEWFOUNDLAND AND LABRADOR

Electric Vehicle Rebate Program

In September 2021, the Government of Newfoundland and Labrador announced a new Electric Vehicle Rebate Program. The program provides $1,966 USD ($2,500 CAD) rebates available to eligible individuals, businesses, not-for-profit organizations or municipalities in NL for the purchase or lease (minimum 48 months) of a new 100% all-electric vehicle, and the purchase of a pre-owned 100% all-electric vehicle.

Electric Vehicle Charging Stations

In 2021, Newfoundland and Labrador Hydro completed the first provincial network of fast chargers across the island portion of the province. The network includes chargers at 14 locations – overcoming a major barrier to EV ownership in the province. The provincial fast-charging network was established in partnership with the Government of Newfoundland and Labrador and Natural Resources Canada and is a critical first step to increasing EV adoption in Newfoundland and Labrador. The network lays the groundwork for additional infrastructure and initiatives in the future, connects the province with the existing national charging network, and brings both environmental and electricity rate benefits for residents.

ONTARIO

Driving Prosperity Plan: Phase 2

In November 2021, Ontario launched Phase 2 of the Driving Prosperity Plan, providing a roadmap to position the province as a North American leader in building the car of the future through emerging technologies, especially electric vehicles. The Plan has an anchor goal to maintain and grow Ontario's auto sector by building at least 400,000 electric vehicles and hybrids annually by 2030.

As part of this work, the province established a Transportation Electrification Council to seek advice from industry leaders and community partners to inform the development of policies and programs to enable EV uptake across the province for personal, commercial, and transit use.

Following the Plan's release, the province announced it is building critical infrastructure by supporting the installation of EV chargers on the province's busiest highways at ONroute stations. This will allow EV owners to travel the province with more freedom and confidence. The Ivy Charging Network chargers will be deployed and available for use at the ONroute locations by the end of 2022.

Ontario Vehicle Innovation Network (OVIN)

Announced in Ontario's 2021 budget, the province of Ontario is investing $44.4M USD ($56.4M CAD) over the next four years to create the Ontario Vehicle Innovation Network (OVIN), Ontario's flagship initiative on automotive and smart mobility technologies.

Building on the success of the Autonomous Vehicle Innovation Network, OVIN's expanded mandate focuses on accelerating the development of next generation electric, connected, and autonomous vehicle and mobility technologies, as well as supporting Ontario's role as the manufacturing hub of Canada.

New OVIN programming includes:

- A new funding program that includes support for electric and low-carbon vehicle technology development projects;
- A new regional technology development site in Northern Ontario that will focus on EV battery technologies and increased collaboration in the mineral sector;
- An OVIN Demonstration Zone, that will support real-time, on-road demonstrations to help Ontario firms showcase made-in Ontario technologies to potential customers; and
- A Skills and Talent Development strategy to help attract and develop world-leading talent in the auto-tech and mobility sectors.

OVIN also functions as a Central Hub that facilitates collaboration between industry, academia and government in the auto-tech and mobility sectors to identify opportunities for partnerships and build awareness and capacity.

QUÉBEC

In 2021, the Québec government launched two 3-year programs aimed at electrifying transport and reducing GHGs.

The Programme d'électrification du transport scolaire (School Transportation Electrification Program), aims to promote the use of electric school buses by financially supporting carriers in the transition of their fleet. The objectives are to achieve an electrification rate for the total school bus fleet of 14% by March 2024 and 65% in 2030. As of December 31, 2021, the program had made it possible to support the purchase of 367 electric school buses in Québec. To date, 505 electric school buses are on the roads of Québec.

The government also renewed its Écocamionnage program (Eco-Trucking Program), which aims to reduce GHG emissions in road freight transportation through measures to improve energy efficiency or through the use of alternative energies.

Greening Government's fleet

In 2021, the Québec government pursued its objective of electrifying vehicles in its government fleet, which had 1,590 electric or plug-in hybrid vehicles as of December 31, 2021. The province's Plan for a Green Economy 2030 has set targets to electrify 100% of its cars, vans, minivans and SUVs and 25% of pickup trucks in the government fleet by 2030.

Publication of the report on the implementation of the Québec ZEV standard

In February 2021, the Québec government published the report on the implementation of the zero-emission vehicle standard. Obligated manufacturers have all met their regulatory obligations for the first compliance period affecting vehicles of model years 2014 to 2018, either by accumulating credits from their own sales or leases of EVs, or by acquiring credits from other manufacturers. The tightening of the standard will be reviewed in light of the findings noted in this report, the gradual increase in requirements already set by the standard, and the ambitious targets set by the government.

YUKON

The Government of Yukon is enabling EV travel to all road-accessible communities in Yukon and is working towards having an EV network that reaches its border entry points at Alaska, British Columbia and the Northwest Territories. In 2021, this included a deployment of 7 additional DC fast chargers, for a current total of 12.

The Government of Yukon is supporting businesses and governments who would like to offer EV charging for workplace, fleet or public use. Yukon offers 75% coverage (rebates) for businesses, up to $5,899 USD ($7,500 CAD); and 90% coverage (rebates), up to $7,079 USD ($9,000 CAD), for municipalities and First Nation governments for level 2 EV chargers.

The Government of Yukon has also run two public education events to raise awareness of the benefits of EVs and how well they function in cold climates. EV owners and dealerships attend and interface with the EV-curious and prospective-EV-owners to provide real-world information about reliability, anticipated range reductions during winter, and key considerations about EV ownership.

HEVS, PHEVS, AND EVS ON THE ROAD

Increased consumer awareness, greater availability of charging infrastructure, improvements in vehicle technology, moreplug-in hybrid electric vehicle (PHEV) and battery electric vehicle (BEV) choices offered by vehicle manufacturers, and federal and provincial purchase incentives, have all contributed to increased EV registrations in Canada in 2021 for passenger vehicles.

At the end of 2021, Canada had 298,211 LDV ZEVs on the road, a 42% increase from the previous year despite the impact from the COVID-19 pandemic. The registrations of battery EVs in 2021 increased 61% from 2020, the registration of HEVs increased by 32%, while the registration of PHEVs nearly doubled from 2020 with 28,281 units registered compared to 14,464 the previous year. Of note, the number of fuel cell vehicles (FCVs) registered in 2021 was 126 vehicles as compared to 16 vehicles in 2020. Registrations of medium and heavy-duty ZEVs and hybrid electric vehicles (HEVs) were nil in 2021.

Source: S&P Global Mobility, Vehicles in Operation, Canada, 2021 calendar year

*Total including ICEVs

Fleet Totals as of December 31st 2021

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	n.a.	n.a.	n.a.	n.a.	n.a.
Electric moped (<50 kmph)	n.a.	n.a.	n.a.	n.a.	n.a.
Auto-rickshaw	n.a.	n.a.	n.a.	n.a.	n.a.
Motorcycle	506	n.a.	n.a.	n.a.	1,169,606
Motorcycle with sidecar	n.a.	n.a.	n.a.	n.a.	n.a.
Motorized tricycle	n.a.	n.a.	n.a.	n.a.	n.a.
Passenger vehicles	187,765	418,973	110,195	251	25,015,342
Buses and Minibuses	431	2549	0	0	72,198
Light Commercial vehicles	n.a.	n.a.	n.a.	n.a.	n.a.
Medium and Heavy Weight Trucks	3	103	0	0	2,612,462

Source: S&P Global Mobility, Vehicle Registration, Canada, 2021 calendar year

*Total including ICEVs

Total Registrations 1st Jan 2021 to 31st Dec 2021

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	n.a.	n.a.	n.a.	n.a.	n.a.
Electric moped (<50 kmph)	n.a.	n.a.	n.a.	n.a.	n.a.
Auto-rickshaw	n.a.	n.a.	n.a.	n.a.	n.a.
Motorcycle	233	n.a.	n.a.	n.a.	84,152
Motorcycle with sidecar	n.a.	n.a.	n.a.	n.a.	n.a.
Motorized tricycle	n.a.	n.a.	n.a.	n.a.	n.a.
Passenger vehicles*	59,433	97,298	28,281	126	1,381,000
Buses and Minibuses	252	289	0	0	1,852
Light Commercial vehicles	2,627	10,291	2,643	28	287,767
Medium and Heavy Weight Trucks	0	0	0	0	95,438

CHARGING INFRASTRUCTURE OR EVSE

Since 2015, the Government of Canada has invested over $354M USD ($450M CAD), to support the demonstration and deployment of ZEV infrastructure to ensure Canadians can charge their ZEVs across the country, through programs such as the Zero Emission Vehicle Infrastructure Program, the Electric Vehicle and Alternative Fuel Infrastructure Deployment Initiative, and the Electric Vehicle Infrastructure Demonstration Program.

At the end of 2021, Canada had 15,236 EV chargers across the country, an increase of over 2,000 chargers from the 13,196 chargers reported in 2020. Significantly, 1,517 of the public chargers are DC fast chargers, 1,300 are Tesla superchargers, and 238 are Ultrafast-High power chargers (DC charging > 150 kW and ≤ 350 kW).

It is important to note that respective jurisdictions do not require registration of EVSEs as they are installed. As a result, tracking of operational charging stations is performed through the issuance of service contracts to collect the charger information, or through voluntary reporting by charging network owners and managers, as well as end users. Level 1 chargers are not reported on, since this infrastructure typically relates to charging via a residential wall outlet.

Source: IHS Markit Vehicles in Operation, Canada, 2021
Electric Charging and Alternative Fuelling Stations Locator.

*As of December 31st 2021

Type of Public EVSE	Number of Charging Points*	Number of Locations*
AC Level 1 Chargers (≤3.7 kW)	n.a.	n.a.
AC Level 2 Chargers (>3.7 kW, ≤22 kW)	12,181	5,608
AC Fast Chargers (43 kW)	0	0
DC Fast Chargers (≤50 kW)	1,517	980
Tesla Superchargers (DC >120kW - 250kW)	1,300	137
Ultrafast-High power chargers (DC >50 kW and ≤350 kW)	238	143
Inductive Chargers (EM charging)	0	0

ZEV DEMONSTRATION PROJECTS

The Government of Canada established the Electric Vehicle Infrastructure Demonstrations (EVID) program in 2016/17, allocating $60M USD ($76M CAD) to support the demonstration of next-generation and innovative EV charging and hydrogen refueling infrastructure projects that address technical and non-technical barriers to the installation, operation, and management of such technologies.

As of 2021, the EVID Program is funding over 20 demonstration projects across the country, such as novel charging technologies and business models for multi-unit residential buildings and workplaces, remote locations and cold climates, bidirectional charging with energy storage, heavy-duty freight, and battery repurposing. In 2021, the EVID Program announced 11 demonstration projects, three of which are highlighted below:

Electric Truck Charging Infrastructure Demonstration

Hydro One Limited will receive up to $3.9M USD ($4.95M CAD) from the EVID program to develop a pilot for heavy-duty electric truck charging stations in Ontario. The project aims to demonstrate scalable prototypes for class 8 heavy-duty electric truck charging, for both return-to-base and highway applications. The project will also incorporate integrated controls that monitor truck charging, account for grid capacity, and provide a means of settlement. The project will also address battery storage requirements to reduce grid impacts and contribute to the establishment of new codes and standards. Hydro One's pilot for electric trucks will be a model for other utilities and businesses interested in pursuing solutions to electrify heavy-duty transportation across Canada.

Alberta Zero-Emissions Truck Electrification Collaboration (AZETEC)

The Alberta Motor Transport Association will receive up to $1.8M USD ($2.3M CAD) from the EVID program to develop and demonstrate a hydrogen fueling station for highway capable, heavy-duty commercial fleet vehicles in Alberta. The hydrogen station will operate in a completely integrated system in real world conditions. AZETEC will validate the design, manufacture, and operation of two long-range fuel cell electric trucks and the supporting hydrogen fueling infrastructure for operation between Calgary and Edmonton, Alberta.

The AZETEC project will look to address barriers to fuel cell electric truck adoption by installing and testing a hydrogen fueling station for highway heavy-duty commercial fleet vehicles using real-world conditions, such as capabilities in climates that range from -30°C to +30°C and the ability to refuel in 20–45 minutes.

Next-Generation Ultra Fast EV Charging Infrastructure

Figure 1: Ultra-Fast Charger in Québec. Image courtesy of Hydro Québec

Hydro Québec, the Province of Québec's state-owned public utility, will receive up to $1M USD ($1.26M CAD) from the EVID program to develop urban & highway sites where ultra fast EV charging infrastructure from various manufacturers ranging from 100 to 350kW will be demonstrated to understand grid infrastructure implications.

The ultra-fast charging stations are in operation at three demonstration sites, which includes Montréal (Laval), where the site is designed to allow access to passenger vehicles as well as medium-duty vehicles, while the other two sites are in service areas along major highways north and south of Montréal, at the Porte-du-Nord service area in St-Jérôme and in Memphrémagog respectively.

The integration of high-speed recharging technology advancements, both for the Circuit Électrique and for the electricity distribution network, makes it possible to test the different charging technologies of several manufacturers in real-life conditions. This project will link the customers of the electric circuit and the manufacturers.

China

MAJOR DEVELOPMENTS IN 2021

In 2021, the Chinese automobile market was hindered by the COVID-19 pandemic, the tight supply of automotive chips, and the increasing price of critical battery materials. However, it still showed strong resilience;the explosive growth of new energy vehicles (NEVs) became the main highlight of the Chinese automobile industry. There was rapid growth in the production and sales of NEVs with an increase of 160% in 2021 as compared with that in 2020. The market share increased to 13.4%, which was 8% higher than that in 2020. This excellent momentum indicates that the development of NEVs has shifted from policy push to market pull, showing better market size and quality development.

Macro Industry Planning

On 24 October 2021, the State Council officially issued the "Working Guidance for Carbon Dioxide Peaking and Carbon Neutrality in Full and Faithful Implementation of the New Development Philosophy", which proposed accelerating the construction of a low-carbon transportation system from three aspects:

- Improving the transportation structure;
- Encouraging the use of energy-conserving and low-carbon vehicles;
- Encouraging low carbon means of transportation.

Among the above-mentioned aspects, the requirements related to NEVs include more rapid development of new energy vehicles and establishment of a convenient and efficient network of facilities for battery charging and swapping.

On 26 October 2021, the State Council officially issued the "Action Plan for Carbon Dioxide Peaking Before 2030", making overall arrangements to achieve a carbon peak by 2030 mentioned in the Working Guidance document. This "Action Plan" document for promoting green and low-carbon transportation highlights that China will vigorously promote new energy vehicles, while gradually reducing the proportion of cars that run on traditional oil-based fuels in terms of new car sales and car ownership. Furthermore, the Action Plan document proposes a specific target by stating that the share of newly sold vehicles fuelled by new and clean energy will reach around 40% by 2030.

Compliance of Credit Policies

China's dual-credit policy for passenger vehicles has achieved good results in promoting the development of energy saving and new energy vehicles, since its official implementation in 2018. As of 2021, the policy has entered the second phase of management, in which the general structure of the Phase 2 policy remains unchanged from the Phase 1 policy. The NEV credit percentage targets for automakers have been increased from 14% in 2021 to 18% in 2023, and fuel-efficient conventional fuel vehicles have been included as a compliance option. In addition, in order to encourage the application of advanced energy saving and emission reduction technologies and to help achieve carbon dioxide peak and carbon neutrality goals, the Ministry of Industry and Information Technology issued the "Notice on the Inclusion of Off-cycle-technology into the Management of Corporate Average Fuel Consumption and New Energy Vehicle Credits for Passenger Vehicles." According to the "Notice" document, for vehicles equipped with brake energy recovery systems or efficient air conditioners with off-cycle energy saving effects, the calculation of their fuel consumption can be reduced by a certain amount according to a fixed quota or test quota.

Fiscal and Tax Policies

To further promote the development of the NEV industry, the Ministry of Finance, the Ministry of Industry and Information Technology, the Ministry of Science and Technology, and the National Development and Reform Commission jointly issued the "Notice on Further Improving the Financial Subsidy Policy for the Promotion and Application of New Energy Vehicles," which further clarified the subsidy measures for NEVs in 2021. To create a stable policy environment, the technical indicator system and threshold requirements for purchase subsidies remained unchanged in 2021. In general, the purchase subsidies for NEVs (non-public sector) in 2021 were 20% lower than those in 2020. To accelerate electrification in public transportation and other fields, such as vehicles for urban public transport, sanitation, and other public sectors[1] , the subsidy standard in 2021 was reduced by 10% as compared with 2020 and the NEV test methods were updated in 2021. Before the new standards were issued and implemented, products tested under the old standards could enjoy subsidies as long as they met the technical threshold requirements. The policy was implemented on 1 January 2021. In summary, the "Notice" document clarified the subsidy standards for different types and fields of vehicle products, providing a basis for the precise implementation of subsidy policies.

Table 1: Changes in subsidy standards for battery electric passenger vehicles in 2020 and 2021 (1 USD equals 6.4515 CNY)

Item	Scope of technical indicators	Subsidy standard/coefficient			
		Non-Public Sector		Public Sector	
		2020	2021	2020	2021
The upper limit of subsidy per unit electricity ($/KWh)	/	$77.5	$62	$85.25	$76.73
Subsidy standard for e-range per vehicle	<300 km	/	/	/	/
	300–400 km	$2511.04	$2015.04	$2790.05	$2511.04
	≥400 km	$3487.56	$2790.05	$3875.07	$3487.56
	125 (inclusive) –140 Wh/kg	80%	80%	80%	80%
	140 (inclusive) –160 Wh/kg	90%	90%	90%	90%
	≥160 Wh/kg	100%	100%	100%	100%
Adjustment coefficient of vehicle energy consumption	Better than the limit value by 0–10% in terms of power consumption per 100 kilometers	80%	80%	80%	80%
	Better than the limit value by 10 (inclusive)–25% in terms of power consumption per 100 kilometers	100%	100%	100%	100%
	Better than the limit value by 25 (inclusive) in terms of power consumption per 100 kilometers	110%	110%	110%	110%

The method for calculating the subsidy standard for battery electric vehicles is as follows:

Subsidy amount for each battery electric passenger vehicle = Min {e-range subsidy standard, vehicle electricity capacity × upper limit of subsidy per unit electricity} × adjustment coefficient of battery system energy density × adjustment coefficient of vehicle energy consumption

Table 2: Changes in subsidy standards for plug-in hybrid electric passenger vehicles (including E-REV) in 2020 and 2021 (1 USD equals 6.4515 CNY)

Item	Scope of technical indicators		Subsidy standard/coefficient			
			Non-Public Sector		Public Sector	
			2020	2021	2020	2021
Subsidy base per vehicle	2020: E-range R ≥ 50 km(NEDC) 2021: E-range R ≥ 50 km (NEDC) E-range R ≥ 43 km (WLTC)		$1317.52	$1054.02	$1550.03	$1395.02
Adjustment coefficient	E-range is less than 80 km (the ratio of fuel consumption to the limit value of conventional fuel consumption under state B in assessment)	Ratio less than 55%	100%	100%	100%	100%
		Ratio between 55% (inclusive) and 60%	50%	50%	50%	50%
	E-range is greater than 80 km (the limit value of energy consumption per 100 kilometers under state A in assessment)	The electricity consumption per 100 kilometers under state A meets the requirements on the limit value of energy consumption of battery electric passenger vehicles	100%	100%	100%	100%

The method to calculate the subsidy standard for plug-in hybrid electric passenger vehicles (including E-REV) is as follows:

Subsidy amount for each plug-in hybrid electric passenger vehicle (including E-REV) = Subsidy base per vehicle × adjustment coefficient

HEVS, PHEVS, AND EVS ON THE ROAD

The stock of NEVs in China has increased by more than one million for four consecutive years, and the production and sales of NEVs in China have ranked first in the world for seven consecutive years. Table 3 shows the stock of electric vehicles on the roads in China from 2017 to 2021. The stock of electric vehicles reached 9.57 million in 2021. The stock of battery electric vehicles (BEVs), hybrid electric vehicles (HEVs), and plug-in electric vehicles (PHEVs) reached 6.40 million, 1.73 million, and 1.43 million, respectively, accounting for 66.88%, 18.08%, and 14.94% of the stock of electric vehicles. Fuel cell vehicles (FCVs) are mainly for demonstration operation and are in the initial stage with a stock of only about six thousand.

Table 3: Annual fleet totals for the period 2017–2021

Source: Ministry of Public Security of the People's Republic of China) (in millions).

*UNECE categories M1,M2,M3,N1,N2,N3.

**HEV and FCV data are from CATARC.

Fleet Totals at the End of 2017–2021*

Vehicle Type	2017	2018	2019	2020	2021
HEVs**	0.46	0.71	1.08	1.49	1.73
BEVs	1.53	2.11	3.10	4.00	6.40
PHEVs	1.53	0.50	0.71	0.91	1.43
FCVs**	0.001	0.002	0.004	0.006	0.006
Total	217	240	260	281	302

Table 4 shows the annual sales of electric vehicles in China from 2017 to 2021. The annual sale of electric vehicles increased by 122.3% in 2021 as compared with the annual sales in 2020. The sales of BEVs and PHEVs increased by 161.5% and 140.2%, respectively, as compared with their sales in 2020. In addition, the annual sales of HEVs increased by 30.2%, reaching up to 681 thousand.

Table 4. Annual total sales from 2017 to 2021 a

Source: CAAM (in thousands).

*UNECE categories M1,M2,M3,N1,N2,N3.

**HEV annual sales data are based on statistical specifications from CATARC.

Total Sales During Years between 2017 and 2021*

Vehicle Type	2017	2018	2019	2020	2021
HEVs**	183	260	382	523	681
BEVs	652	984	972	1115	2916
PHEVs	124	271	232	251	603
FCVs	1.3	1.5	2.7	1.2	1.6
Total	28,879	28,081	25,769	25,311	26,275

Product diversification has become the main driving force for the development of the NEV market, and an accurate product definition is the key to triggering demand. HongGuang Mini EV has effectively met the consumers' demands for low-speed electric vehicles and has become the most popular model in China with a very high-cost performance ratio. The sales reached 392,000 in 2021, driving the sustained high growth of the mini-car market. Leading auto manufacturers such as Tesla and

BYD, etc. have achieved excellent performances with diversified product portfolios. Among them, the annual sales of Tesla Model Y and Model 3 reached 322,000, due to their top intelligence level and technological attributes. Many of BYD's products, such as Qin and Han, which are innovative in styling and advanced in technology, have performed well in the battery and plug-in hybrid electric passenger vehicle markets. The BYD brand achieved annual sales of 720,000 in 2021. New domestic auto manufacturers represented by NIO, XPENG, and LEAD INGIDEAL have won the favor of users with innovative products and leading service concepts, achieving 279,000 sales in 2021.

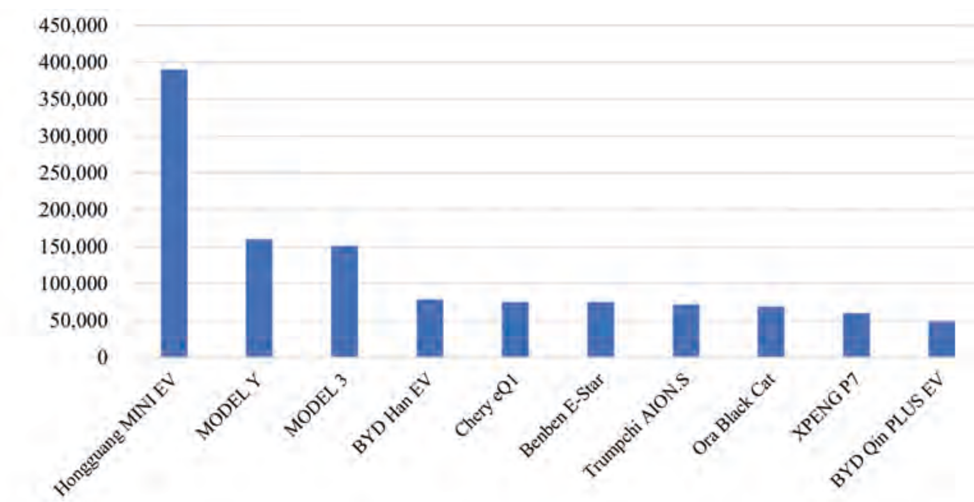

Figure 1. 2021 Annual sales of battery electric passenger vehicles for market leaders

Source: CATARC

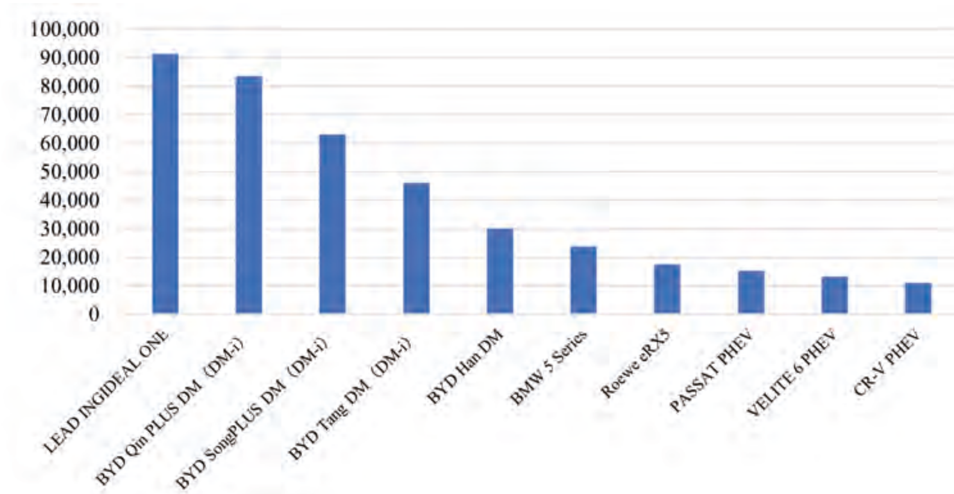

Figure 2. 2021 Annual sales of plug-in hybrid electric passenger vehicles (including E-REV) for market leaders

Source: CATARC

CHARGING INFRASTRUCTURE OR EVSE

According to the data of the China Electric Vehicle Charging Infrastructure Promotion Alliance, by the end of 2021, there were 2.617 million charging pillars in China, which was an increase of 70.1% as compared with in 2020. The ratio of NEVs to charging pillars is about 3:1. By the end of 2021, there were 1.147 million public charging pillars and 1.470 million private charging pillars, representing an increase of 65% and 74.3%, respectively, as compared with that in 2020. The battery swapping mode of EVs has also begun to take shape, and the number of battery swapping stations has reached 1298 nationwide, representing an increase of 133.9% as compared with the number of stations in 2020.

Table 5. Public charging infrastructure on 31 December 2021

Source: China Electric Vehicle Charging Infrastructure Promotion Alliance)

Type of Public EVSE	Quantity
AC Charging pillars	677,000
DC Charging pillars	470,000
Total charging pillars	**1,147,000**
Battery Swapping Station	1298

Regarding geographical distribution, the public charging pillars are concentrated in Guangdong, Shanghai, Jiangsu, Beijing, Zhejiang, Shandong, Hubei, Anhui, Henan, and Fujian, accounting for 71.7% of the total public charging infrastructure, whereas the northeast, northwest, and southwest areas have relatively fewer facilities. The distribution of public charging pillars in China is shown in Figure 3.

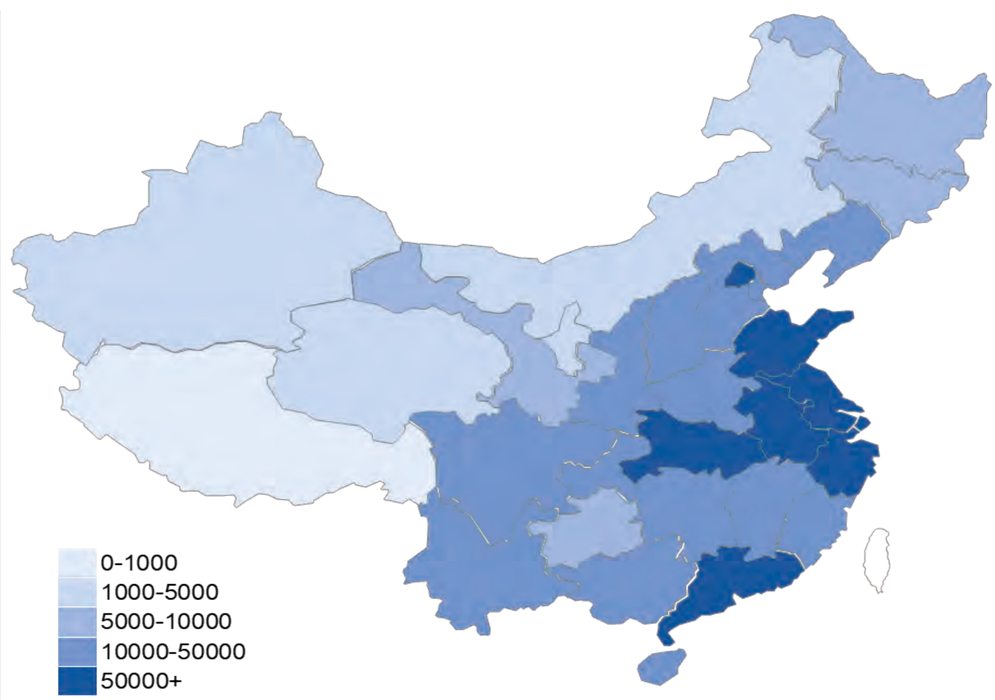

Figure 3. Distribution of the public charging pillars in China by December 31, 2021

Source: China Electric Vehicle Charging Infrastructure Promotion Alliance)

With respect to charging infrastructure operators, a large-scale operator-dominated market has formed comprising small and micro-operators. As of 2021, there were 32 large-scale operators (charging pillars ≥1000) in China, of which 13 operators (charging pillars ≥10,000) accounted for 92.9% of the total public charging market.

EV DEMONSTRATION PROJECTS

Battery Swapping

In 2021, the Ministry of Industry and Information Technology issued the “Notice on Pilot Application of Battery Swapping Mode for New Energy Vehicles”. There are 13 cities included in the pilot, including eight comprehensive cities (Beijing, Nanjing, Wuhan, Sanya, Chongqing, Changchun, Hefei, and Jinan) and three cities with a number of heavy trucks (Yibin, Tangshan, and Baotou). These cities have good industrial bases, experience in battery swapping mode, the potential for energy conservation/ emission reduction, and strong policy support.

The overall sales of battery swapping passenger vehicles, in 2021, were 113,074, which was an increase of 116.6% from the previous year. NIO and BAIC were the main sellers of battery swapping products. NIO’s 2021 sales dropped significantly as compared with those in 2020, accounting for less than 80% of the market, since many new competitors were entering the market. Non-operating models accounted for 81% of the sales of battery swapping products, almost all of which were NIO, while other brands’ products were mainly rental.

In terms of commercial vehicles, regarding the key area of air pollution prevention and control, heavy trucks using battery swapping technology have begun to enter the market. In 2021, the overall sales were 3320, of which 88.7% were heavy-duty trucks. In addition, 40% of the heavy trucks using battery swapping technology were sold to Tangshan.

There are two main reasons: First, Tangshan has started an application for a pilot project on NEV battery swapping mode. Second, Tangshan is a port city with a developed heavy industrial base, and its ecological environment needs to be improved. Heavy trucks using battery swapping technology are suitable for short-distance and high-frequency usage scenarios such as port barges, logistics parks, and steel mill short barges, and therefore, they have been rapidly promoted.

OUTLOOK

China’s new energy passenger vehicle market, especially in the high-end and low-end product markets, is increasing rapidly due to the gradual improvement of new energy vehicle technology, vehicle product portfolios, comprehensive support policies, and charging infrastructure. In the future, regarding new energy passenger vehicles, the market potential of small- and medium-sized cities and vast rural areas in China is enormous, which will be the focus for future development of new energy passenger vehicles. Regarding new energy commercial vehicles, the development of medium- and heavy-duty new energy commercial vehicles is in the initial stage and will usher in a period of rapid development.

References

[1] Public sector vehicles include city buses, road passenger vehicles, taxis (including ride-hailing vehicles), sanitation trucks, urban delivery trucks, postal trucks, airport vehicles, and government vehicles.

Finland

MAJOR DEVELOPMENTS IN 2021

EV sales

Sales of electric passenger vehicles increased, with 59% of new vehicles having at least a hybrid electric powertrain. Although only 7% of the total fleet has at least a hybrid electric powertrain, more than a quarter (28%) of those were new from 2021, so the fleet renewal is picking up speed.

Exactly half of the new buses in Finland are electric, with no new hybrid buses. The change evidenced in 2021 was dramatic, as the new buses constitute two thirds of the total electric bus fleet in Finland.

Although the sales of electric light commercial vehicles amounted to only 5% of the total, the size of electric light commercial fleet almost doubled during 2021, showing increasing interest in electric light commercial vehicles.

The sales of electric trucks are still very low, but with an increase expected in the coming years, as more models come available.

Active policies

The car tax (paid when the vehicle is first registered) percentage is based on the CO2-emissions of the car, with higher emissions taxed harder. For electric and hydrogen cars, the tax is 0%, while the maximum percentage is 50% for cars with emissions of 360+ gCO2/km (WLTP). The vehicle tax (paid annually) has two parts: the basic part being based on the CO2-emissions of the car (53,29-65,444 EUR/year) and the power source part based on the used power source (gasoline, diesel, electricity, etc.) multiplied by the weight of the car.[1]

The taxable value of electric company cars used by a company's employee is reduced by 170 EUR per month for both free use (company pays for everything) and operating use (employee pays for electricity). For free use cars, an additional 120 EUR per month (or 0.08 EUR per kilometer) reduction is also in place. The charging of a company car at either work or public charging point is also tax exempted for both electric and hybrid cars. These incentives are in place for the years 2021-2025. From now on, a home charging point for employees is considered an optional extra for electric and hybrid company cars when calculating their taxable value.[2]

There are also three purchase incentives for EVs in place:

- A purchase incentive is in place for years 2022-2023, targeted at private persons buying or leasing an electric vehicle. The subsidy is granted for a purchase or at least 3-year lease of a battery electric vehicle, with a maximum purchase price of 50,000EUR, including taxes. The amount of the subsidy is 2,000EUR.[3]

- A purchase incentive is in place for year 2022, targeted at private persons buying or leasing an electric van. The subsidy is granted for a purchase or at least 3-year lease of a battery electric van. The amount of the subsidy is 2,000- 6,000EUR, depending on the size of the van.[4]

- A purchase incentive is in place for years 2022-2023, targeted at private persons buying or leasing an electric truck. The subsidy is granted for a purchase or at least 3-year lease of a battery electric truck. The amount of the subsidy is 6,000-50,000EUR, depending on the size of the truck.[5]

There are two subsidies in place for building EV charging infrastructure, with one aimed for housing companies and the other for workplaces:

- Subsidy for housing companies for building EV charging infrastructure. The subsidy covers 35% of the costs incurred from building electrical system surveys, wiring installations, and charging equipment. The minimum requirement is to build readiness for five charging points.[6]

- Subsidy for workplaces for building EV charging infrastructure for 2022 and 2023. The subsidy amounts to 750 EUR/charger and has 1.5 MEUR reserved for both years.[7]

HEVS, PHEVS, AND EVS ON THE ROAD

The biggest brand in new electric passenger vehicles in 2021 was Volkswagen with 2,411 new EVs, Tesla (1,516 new EVs) and Hyundai (815 new EVs) followed in second and third place. In plug-in hybrid electric vehicles, the top three brands are Volvo (3,818 new PHEVs), BMW (3,190 new PHEVs) and Mercedes-Benz (2,773 new PHEVs).[8]

Fleet Totals (as of December 31st 2021)[8,9]

*Total including ICEVs

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	n.a.	n.a.	n.a.	n.a.	n.a.
Electric moped (<50 kmph)	2901	n.a.	0	0	105063
Auto-rickshaw	n.a.	n.a.	n.a.	n.a.	n.a.
Motorcycle	64	n.a.	0	0	144929
Motorcycle with sidecar	n.a.	n.a.	n.a.	n.a.	n.a.
Motorized tricycle	146	n.a.	0	0	11898
Passenger vehicles	22921	105651	76990	2	2755349
Buses and Minibuses	271	14	2	0	10476
Light Commercial vehicles	796	477	182	0	343927
Medium and Heavy Weight Trucks	9	26	0	0	94771

Total Sales 1st Jan 2021 to 31st Dec 2021[8,9]

*Total including ICEVs

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	n.a.	n.a.	n.a.	n.a.	n.a.
Electric moped (<50 kmph)	943	n.a.	0	0	4380
Auto-rickshaw	n.a.	n.a.	n.a.	n.a.	n.a.
Motorcycle	25	n.a.	0	0	3707
Motorcycle with sidecar	n.a.	n.a.	n.a.	n.a.	n.a.
Motorized tricycle	17	n.a.	0	0	271
Passenger vehicles	10152	28106	20144	1	98484
Buses and Minibuses	191	0	0	0	382
Light Commercial vehicles	340	280	38	0	12893
Medium and Heavy Weight Trucks	2	0	0	0	3536

*As of December 31st 2021

CHARGING INFRASTRUCTURE OR EVSE

Type of Public EVSE[10]	Number of Charging Points*[10]	Number of Locations*[10]
AC Level 1 Chargers (≤3.7 kW)	n.a.	n.a.
AC Level 2 Chargers (>3.7 kW, ≤22 kW)	5820	1598
AC Fast Chargers (43 kW)	n.a.	n.a.
DC Fast Chargers (≤50 kW)	401	285
Tesla Superchargers (DC >120kW - 250kW)	78	12
Ultrafast-High power chargers (DC >50 kW and ≤350 kW)	288	145
Inductive Chargers (EM charging)	0	0

EV DEMONSTRATION PROJECTS

The city of Helsinki, in co-operation with Forum Virium Helsinki, University of Applied Sciences Tampere, and VTT Technical Research Centre of Finland are investigating electrification of the fleet of Helsinki City Construction Services (Stara). The Stara eRetrofit project, launched in September 2019, aims to assess the effects and costs of the electrification of Stara's operational fleet.

The focus of the assessment is on electrification retrofits and the project plan includes development of technical electrification plans and actual electrification of one heavy-duty truck. The project has faced schedule problems caused by the global pandemic and related component supply issues.

Helsinki Region Environmental Services Authority (HSY) is going to pilot electric refuse truck operation in 2022. The pilot will last until spring of 2023 with the aim to investigate the operation of a battery electric refuse truck in arctic conditions. Low noiselevels and lack of tailpipe emissions in the narrow city streets are some of the foreseen benefits of the electrification of refuse truck operation.

OUTLOOK

The Finnish government has decided on a roadmap to fossil-free transport, which includes the intermediate goal of halving the CO2-emissions from transport by 2030 (compared to 2005), with the ultimate goal of fossil-free transport by 2045. This roadmap includes the intermediate targets of 700,000 passenger EVs and 45,000 light commercial EVs (of which at least 50% are fully electric) and 4,600 electric trucks and buses by 2030, and 2 million fully electric passenger vehicles by 2045.[11]

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France

MAJOR DEVELOPMENTS IN 2021

Despite a difficult year for the automotive sector, the development of electric mobility in France continued to progress drastically throughout the year.

Now, over the year 2021, the sales of electric vehicles represented more than 15% of all the vehicles sold in France. It represents 315 978 registrations, over a total of 2 091 633 all fuel vehicles. A total of 786 274 electric vehicles are circulating in France (+67% compared to 2020).

To reduce the impact of transport on the environment and achieve the objective of carbon neutrality in 2050, the French Government is committed to the development of electric mobility. The objective of EV sales for 2022 is 1 million, which seems to be achievable.

New policies, legislation, incentives, funding, research, and taxation

FLEET RENEWAL

The Energy Transition Law for Green Growth (LTECV) obliges certain players (State, Public establishments, communities, national companies) to integrate a share of environmentally virtuous vehicles (low emission vehicles) for the acquisition or use of vehicles. Since the Mobility Law, voted at the end of 2019, this integration is guided by new regulations. At least 50% of new vehicle acquisitions from the state and public establishments must be low-emissions vehicles. For communities and national companies, this proportion is set at 20% before July 2021 and 30% after that date. France further imposed obligations on vehicle fleet managers, motor vehicle rental companies, taxi operators and operators of chauffeur-driven transport vehicles to purchase or use low-emission vehicles.

COMPANY VEHICLE TAX (TVS)

In France, companies are subject to the company vehicle tax (TVS). The TVS is applied according to a progressive scale based on the amount of CO2 emitted by the vehicle. The nature of this progressive scale aims to encourage companies to renew their fleet of vehicles in favour of less polluting vehicles.

ECOLOGICAL BONUS / MALUS

Through the automotive bonus/malus system, and in the more general framework of French policy in favour of ecological transition, the Government aims to support, through financial aid, the acquisition and rental of low-emission vehicles, the choice of a new vehicle with low CO2 emissions, and discourage, via a penalty, the purchase of more polluting vehicle models.

In 2021, the bonus remains available, with some amount lightly decreased in comparison with 2020:

- Up to € 6,000 (within the limit of 27% of the acquisition cost) for the purchase of a new private car or a van emitting 20 grams of CO2 / km or less. In this range of emissions, the aid for a second-hand car can be up to € 1,000.

- Up to € 2,000 for the purchase of a new private car or a van emitting between 21 grams of CO2 / km and 50 grams of CO2 / km.

- Up to €1,000 for the purchase of a new electric 2-or 3-Wheeler.

- Up to €1,000 for the purchase of Plug-In Electric Vehicle

- Up to €50,000 (within the limit of 40% of the acquisition cost) for the purchase of a new electric of hydrogen heavy weigh vehicle.

These amounts are increased by €1,000 when you live in French overseas territories.

CONVERSION BONUS

This aid is available when a new vehicle is bought to replace a diesel vehicle older than 2011 or a gasoline vehicle older than 2006. A conversion bonus can be cumulated with the ecological bonus. The aid depends on the emission of the new vehicle acquired:

- Up to €5,000 for a new vehicle EV or PHEV (depending on your salary)
- €1,100 for a new electric 2- or 3- Wheeler

Additional bonus is now available for retrofitted diesel/gasoline vehicle to electric vehicle:

- Up to €5,000 (depending on your salary) for cars
- Up to €9,000 (depending on your salary) for vans
- Up to €1,100 for electric 2-or 3-Wheeler.

HEVS, PHEVS, AND EVS ON THE ROAD

*Total including ICEVs

Fleet Totals (as of December 31st 2021)

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	n.a.	n.a.	n.a.	n.a.	~1 750 000
Motorcycle	n.a.	n.a.	n.a.	n.a.	57 527
Passenger vehicles and Light Commercial vehicles	n.a.	n.a.	n.a.	n.a.	512 178
Buses and Minibuses	896	n.a.	76	21	974
Medium and Heavy Weight Trucks	n.a.	n.a.	n.a.	n.a.	n.a.

*Total including ICEVs

Total Sales 1st Jan 2021 to 31st Dec 2021

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	n.a.	n.a.	n.a.	n.a.	514 672
Motorcycle	23 000	n.a.	n.a.	n.a.	23 000
Passenger vehicles and Light Commercial vehicles	174 000	n.a.	141 000	n.a.	315 000
Buses and Minibuses	600	n.a.	n.a.	n.a.	600
Medium and Heavy Weight Trucks	12 000	n.a.	800	n.a.	12 800
	50	n.a.	n.a.	n.a.	50

CHARGING INFRASTRUCTURE OR EVSE

*As of December 31st 2021

Type of Public EVSE	Number of Charging Points*	Number of Locations*
AC Level 1 Chargers (≤3.7 kW)	19 718	n.a.
AC Level 2 Chargers (>3.7 kW, ≤22 kW)	30 077	n.a.
AC Fast Chargers (43 kW)	-	n.a.
DC Fast Chargers (≤50 kW)	894	n.a.
Tesla Superchargers (DC >120kW - 250kW)	n.a.	n.a.
Ultrafast-High power chargers (DC >50 kW and ≤350 kW)	2737	n.a.
Inductive Chargers (EM charging)	n.a.	n.a.

CHARGING INFRASTRUCTURE OR EVSE

One of the essential conditions for the development of electric mobility is the availability and accessibility of charging infrastructures. At the end of 2021, more than 53,000 charging points open to the public were installed in France (+64% compared to 2020). It represents 80 000 charging points per 100 000 inhabitants.

The French government has set a target of 7 million public and private charging points by 2030. It also set a short-term objective of 100,000 public charging points at the end of 2021. This very ambitious target has not been reached, although very ambitious financial supports.

The government has put in place a series of measures to promote the deployment of the charging infrastructure network for electric vehicles. Depending on the type of infrastructure and the project owner, there are different financial aids for the installation of a charging point:

THE ADVENIR PROGRAM

Its new target is to fund 60,000 private charging stations in car parks (shops or businesses) and collective housing through financial assistance for 2023. This programme benefits from a € 200M budget available during the 2020-2023 period. It is funded through energy-saving certificates. The programme helps to install chargers for co-funded projects from collective housing, for public and private parking lots, for fast charging stations. It is also available for the upgrading of old chargers.

OTHER FINANCIAL TOOLS

All individuals can access a €300 tax credit to contribute to the installation of a private charging point. This help can represent 75% of the cost of the charging point, to a maximum of 300€. The reduction rate has been increased from 40% to 75% to take into account grid connection costs for publicly accessible chargers, until the end of 2021, and for electric bus chargers until the end of 2022. Additional financial support of € 100M will help the development of fast-charging stations on major national roads.

LEGAL TOOLS

Local authorities have the power to implement a charging infrastructure development plan. Individuals have the right to install a charger in collective buildings. Finally, there are obligations to pre-equip and equip parking lots with charging infrastructures.

Germany

MAJOR DEVELOPMENTS IN 2021

2021 marks a turning point for the uptake of electric vehicles in Germany. One quarter of newly registered cars were battery electric (BEVs) and plug-in hybrid vehicles (PHEVs), representing a doubling of their market share compared to 2020. In November 2021, for the first time more BEVs were sold than diesel cars, a traditionally strong market segment in Germany since the late Nineties[1]. Despite the high market shares of electric vehicles sold in 2021, they represent merely 2.4 % of the stock on 1 January 2022.

There is a need to provide charging infrastructure to facilitate the market uptake of electric vehicles. By the end of 2021, there are 49,969 charging points in Germany, of which 41,812 are normal and 8,157 are fast charging points at a total of 25,868 publicly accessible charging facilities. This equivalates to an increase by nearly 31% compared to the number of charging facilities in 2020.

New car registrations in Germany dropped by 10% compared to 2020, amounting to 2.6 million units sold. This is a decrease in registrations by 10% compared to 2020, largely driven by a shortage in supply due to the semiconductor crisis. Compared to the last pre-Covid year 2019, in 2021 almost 1 million less cars were sold[2].

A shortage in semiconductors has had a strong impact on the German automotive industry in 2021, forcing manufacturers and major suppliers to temporarily halt or reduce their production capacities. This led to a total reduction in domestic vehicle production of about 12% to 3.1 million units. Already in 2020, the German production of light duty vehicles dropped by about 25% compared to the previous year: from 4.7 million in 2019 to 3.5 million vehicles in 2020[3]. In consequence of the semiconductor shortages, German manufacturers have shifted their production portfolio to upper-class models like the (all-electric) EQS or the S-Class.

Germany continued working closely with other EU member states to develop battery and fuel cell production. According to the plans of automotive manufacturers and suppliers in Germany, a total of over 400 GWh of battery capacity per year is to be built up by 2025[20]. The implementation phase of the Important Project of Common European Interest (IPCEI) on hydrogen technologies and systems in Germany started in May 2021, including 62 hydrogen projects to receive a total of 8 billion euros in public funds. It is expected to unlock a total of 33 billion euros investments and is therefore considered the largest hydrogen related project in Europe. Among the projects selected features the construction of a large fuel cell production facility by Cellcentric, illustrating that the funding program also places a strong focus on hydrogen applications in the transport factor; however, with a focus on heavy-duty applications for the time being[4].

In 2021, CO2 emissions in Germany have increased by 4.5 % compared to 2020. The transport sector caused 148 million tonnes CO2 equivalent emissions, an increase by 1.2 % compared to the previous year[6]. This means that the transport sector target failed to meet the sector target of 145 million tonnes CO2 equivalent emissions in 2021, stipulated in German's climate law – despite passenger car travel demand still being affected by the Corona pandemic and accompanying measures.

In September 2021, a new government was elected, composed of three parties: the SPD, Greens, and FDP. A main element regarding electromobility represents the new government's target for 15 million electric vehicles on German roads and one million charging stations by 2030[7].

New policies, legislation, incentives, funding, research, and taxation

NATIONAL CENTRE FOR CHARGING INFRASTRUCTURE

Andreas Scheuer, former Federal Minister of Transport and Digital Infrastructure, launched on 6th October 2020 the operational phase of the National Centre for Charging Infrastructure. On behalf of the German Federal Ministry of Transport and Digital Infrastructure, the National Centre for Charging Infrastructure – under the umbrella of the federally owned NOW GmbH – coordinates and controls activities to expand the charging infrastructure in Germany. Objectives are[10]:

- Set up of one million public charging points by 2030.
- Development of a public fast charging network with 1,000 sites by the end of 2023.
- Acceleration of the development of private charging infrastructure through financial support and better legal framework conditions.
- Development of a user-friendly and reliable public charging infrastructure with easy-to-find charging stations and a transparent fee structure and payment methods.

In November 2021, the German government announced to accelerate the construction of one million charging points to be completed by 2030, with a focus on setting up fast charging stations[7].

ELECTRIC VEHICLE PURCHASE BONUS SCHEME FOR NEW VEHICLES

In 2016, the Federal Government introduced the "Umweltbonus" (environmental bonus), a purchase bonus for electric vehicles aimed at promoting their market uptake. Half of the environmental bonus is paid by the car manufacturers and half by the government[11]. In February 2020, the government increased the bonuses and extended the program until December 2025.

As part of an economic stimulus package introduced in June 2020 in response to the

Corona crisis, the German government temporarily introduced an additional purchase bonus ("Innovationsprämie")[12], which doubles the federal share of the environmental bonus (while the manufacturers' share remains unchanged). The increased bonus rates are in place from 3 June 2020 to 31 December 2022.

The purchase bonus applies different rates to the acquisition of new full electric cars and vans (BEVs and fuel cell electric vehicles) and PHEVs[7]. A higher premium is paid for vehicles with a list price of the basic version of a model up to 40,000 euro (excluding GST), compared to vehicles with a list price up to 65,000 euro. The current bonus for full electric vehicles with a price up to 40,000 euro amounts to 9,000 euro. More expensive vehicles up to 65,000 euro benefit from a bonus of 7,500 euro. PHEVs are still in the scheme, with the rate amounting to 6,750 euro for vehicles with a price up to 40,000 euro. The bonus for PHEVs with a net list price between 40,000 and 65,000 euro amounts to 5,625 euro[13]. These rates are in place until December 2022 and apply to buyers of new electric vehicles.

Bonuses are also provided for leasing contracts of new electric vehicles, as well as the purchase of used vehicles up to an age of 12 months, in case these had not benefitted from the bonus scheme previously. The following table summarises the rates available for full electric vehicles according to the current scheme in place, valid until December 2022.

Table 1: Purchase bonuses (environmental and innovation bonuses) for battery electric and fuel cell vehicles[13]

	Vehicles with list price up to 40,000 euro	Vehicles with list price 40,000 -65.000	Minimum holding period
Purchase	9,000 EUR	7,500 EUR	6 months
Leasing term 6-11 months	2,250 EUR	1,875 EUR	6 months
Leasing term 12-23 months	4,500 EUR	3,750 € EUR	12 months
Leasing term over 23 months	9,000 EUR	7,500 EUR	24 months

To access the government funded part of the bonus, the buyer/leaser needs to submit an application to the Federal Office for Economic Affairs and Export Control after the vehicle has been registered.

In December 2021, the German government announced to modify the purchase bonus scheme. From 2023 onwards, the scheme will be designed to subsidize only those electric vehicles that can demonstrate to contribute to CO2 emission reductions, e.g., by introducing stricter requirements for PHEVs regarding the electric part of driving and minimum range of the vehicle[14].

Overall, electric vehicle purchase bonuses have been running more than five years. In 2021, the number of applications has increased significantly. The cumulative number of applications more than doubled for BEVs and for PHEVs in 2021. Until the 1st of February 2022, a total 1,084,212 applications have been handed in, which distributes among the vehicle categories as follows[15]:

- BEVs: 607,124 (56%)
- PHEVs: 476,855 (44%)
- FCEVs: 233

Among the top 10 applications per manufacturer/brand are Volkswagen (15.5%), Mercedes-Benz (10.3%), Renault and BMW (around 9%) and Tesla (5.8%). On average, the vast majority of applications were submitted by private individuals and companies: 43.8% and 54.3% respectively[15].

The 10 most popular models benefitting from the purchase bonus schemes are illustrated in the following table.

Table 2: The 10 most popular supported vehicle models[15]

Manufacturer/Brand	Vehicle model	Number of vehicles
Volkswagen	e-up!	40,569
Tesla	Model 3 2021	31,758
smart	EQ fortwo (MY 2017)	24,875
Volkswagen	ID.3 Pro Performance 150 kW	21,563
smart	EQ forfour (MY 2017)	14,757
Volkswagen	Golf GTE eHybrid	14,723
Volkswagen	e-Golf (MY 2017)	14,669
MINI	Cooper SE 3-Türer	12,884
Volkswagen	e-Golf	12,722
Tesla	Model 3 2020	12,279

CREDITS FOR ELECTRICITY USED IN BATTERY ELECTRIC VEHICLES

The “greenhouse gas quota” in Germany is based on the EU’s Renewable Energy Directive and obliges suppliers of petrol and diesel to gradually decrease CO2 emissions from the production and use of fuels and to increase the renewable energy share of the road sector. Since 2017, fuel suppliers can demonstrate decreases in CO2 emissions through the purchase of CO2 credits from the use of electricity in battery electric vehicles. Recently, market intermediaries emerged, offering the possibility to private electric vehicle owners to buy their credits, either based on a fixed price (such as 200 euro per year) or according to the market rates of the certificates, less transaction fees.

CO2 PRICE ON PETROL AND DIESEL

Since 1st January 2021, a CO2 price is applied to the carbon content of diesel and petrol, thereby increasing the pump price of fuels for conventional cars. In the first year of its introduction, the price is set to 25 euro per tonne CO2. This translates into an increased petrol price of 6 ct and 8 ct for diesel, respectively[16]. By 2025, the CO2 price law (“Brennstoffemissionshandelsgesetz”) stipulates a gradual increase of the CO2 price to 55 euro per tonne emitted.

AUTOMOTIVE INDUSTRY

The German automotive industry adjusts to the stricter EU climate policy and accompanying CO2 fleet targets. For example, Daimler intends to sell 100% battery electric cars by the end of this decade. Worldwide, German OEMs produced over

650,000 passenger cars with an all-electric powertrain in 2021[18]. In the first half of 2021 the share of electric vehicles (including hybrids) ranged between 15,8% and 21,7% of the total German car production[19].

Major investments are being made in the construction of new batteries for electric vehicles and the expansion of existing production capacities. According to the plans of automotive manufacturers and suppliers in Germany, a total of over 400 GWh of capacity per year is to be built up by 2025, including the plans of CATL (approx. 100 GWh, Erfurt), Volkswagen (approx. 24 GWh, Salzgitter), SVOLT (approx. 24 GWh, Überherrn), ACC (approx. 24 GWh, Kaiserslautern), CALB (approx. 20 GWh, Farasis (approx. 16 GWh, Bitterfeld), Blackstone Resources (approx. 5 GWh, Döbeln), Leclanché (approx. 2.5 GWh, Willstätt) and the Cellforce Group (joint venture of Porsche and Customcells, up to approx. 0.4 GWh, Reutlingen)[20]. The largest battery plant, however, is currently being built by Tesla in Grünheide, which - in its maximum expansion stage - should enable the production of up to 200 GWh of battery capacity per year. The combination of vehicle production plant, battery plant, and recycling plant is expected to create approx. 12,000 jobs, enabling the production of about 500,000 vehicles per year[21]. The building permit has now been officially issued.

According to the Mercedes-Benz Strategy Update from July 2021, the company intends to install a capacity of more than 200 GWh battery cell production capacity worldwide by 2030. Today, Mercedes-Benz offers battery electric vehicles in all segments in which the brand is represented. By 2025, the company plans to offer “an all-electric alternative for every model” and ideally to sell only electric cars by the end of the decade. In 2021, Merzedes Benz released four new BEVs in the year 2021. One of them, the premium class vehicle EQS, which is a fully electric counterpart of the famous S-Class[22].

The Mercedes EQS is an all-electric four-door luxury sedan covering ranges of up to 784 km (based on the WLTP and depending on the vehicle configuration). The vehicles are being produced based on the newly developed EVA2 platform in the Mercedes-Benz Factory 56 in Sindelfingen. The customer can choose among different battery sizes and drive variants with a maximum usable lithium-ion battery size of up to 107.8 kWh and maximum system power output of 385 kW. The EQS uses a 400 V battery system with a weight of around 700 kg that can be charged with up to 200 kW. Under the best conditions, this can lead to an additional 300 km in 15 minutes when charged via a DC-fast-charger with 500 Ampere[24,25].

Figure 1: Mercedes-Benz EQS while charging. Image courtesy of Mercedes-Benz[24].

At the beginning of 2022, Mercedes-Benz presented the VISION EQXX. A concept car that claims to achieve ranges of more than 1000 km just on a single charge of the 100 kWh battery pack. To reach this goal, the energy consumption of the vehicle has to be lower than 10 kWh/100km. Therefore, they reduced the aerodynamic drag coefficient to 0.17 and reached an energy efficiency of the powertrain of 95%[27].

The Volkswagen brand nearly doubled its global deliveries of electric vehicles (including PHEVs) in 2021; from 212,000 in 2020 to 369,000 in 2021. The share of BEVs rose from 63% to 71% regarding all produced electric vehicles and counts for more than 5% of all produced vehicles of the brand in 2021. Demand for electric vehicles also remains very high, with an order backlog of 95,000 all-electric vehicles of the ID-family[29]. By 2030, Volkswagen aims to deliver at least 70% of European vehicle sales with fully electric drive systems. Volkswagen aims to invest up to 16 billion euros in e-mobility technologies and digitalization by 2025. The Group plans to launch a new battery electric model each year until 2030[30].

Figure 2: Volkswagen ID.Buzz was launched in March 2022. Image courtesy of Volkswagen[32]

Volkswagen will hand over the first ID.Buzz to customers in Fall 2022. The model is the remake of the traditional VW transporter which started in the 1940s. The ID.Buzz is based on Volkswagen's MEB platform (MEB is the abbreviation for "Modulare E-Antriebs-Baukasten" which translates as Modular Electric Drive Kit) and has the same battery and powertrain system as the ID.3, ID.4 and ID.5.

The ID.Buzz will be available at the start with a 150 kW electric motor on the rear, and later also with 300 kW and all-wheel-drive. The vehicle will get the 77 kWh net battery system first, which would allow the ID.Buzz to get ranges of around 400 km. Later the Buzz will be available also with the 52 kWh net battery (Pure) and in 2023 Volkswagen plans an XL-Version of the ID.Buzz with a potentially even larger battery. The vehicle will be able to be charged with AC and DC and will also be fully fast-chargeable. The top version charges from 5 to 80% with up to 170 kW in around 30 minutes. The ID.Buzz will be ready for bi-directional charging and along with the ID.Buzz, Volkswagen is simultaneously introducing Plug & Charge at the charging points, eliminating the hassle of authentication before charging[32].

In the end of 2020, after more than 80,000 produced vehicles and because of delivery times of more than 16 months, Volkswagen stopped orders for their electric microcar e-up!. In 2021, another 30,800 already ordered vehicles were produced, resulting in Germany's second most popular electric vehicle. In early 2022, Volkswagen announced that their popular entry-level electric vehicle would be available to order again, providing a low-cost alternative until the entry-level vehicle of the ID-family will appear[33].

HEVS, PHEVS, AND BEVS ON THE ROAD

New car registrations in Germany in 2021 have cumulated to 2,622,132. This is another 10% drop in registration figures compared to 2020, the year of the beginning of the COVID-19 pandemic. BEV sales experienced a growth of more than 83% year-on-year, from 194,163 to 355,961. PHEV sales increased by 62%, from 200,469 in 2020 to 325,449 vehicles in 2021. With more than 92% of them powered by gasoline engines. The sales of HEVs increased by a factor of 1.3 to 429,139 vehicles including approx. 315,000 mild-hybrids*. New registrations of conventional gasoline vehicles fell by 28.6%, dropping to 972,000 vehicles, which corresponds with a market share of 37,1%. Diesel vehicles fell even more sharply by 36% compared with 2020, dropping to 524,446 vehicles with a market share of 20%[1].

* Based on DLR internal analysis of KBA and ADAC data.

One third of vehicles were registered by private owners, leaving around 1.7 million vehicles commercially registered. More than a quarter of the overall registered vehicles are SUVs, relegating the long-term segment winner, compact cars, to second place only with a share of 17.5%, followed by small vehicles with 14.3% and off road vehicles with 10.7%. The mini segment recorded the largest increase in newly registered vehicles up to 16.5%, while larger vehicles such as vans and utilities suffered declines of around 30%[34].

The share of new BEVs in each vehicle segment was highest for minis, with a share of 47.3% out of all new mini registrations, followed by luxury class vehicles with a share of 29.1%[35].

As of 1st January 2022, 59.64 million motorized vehicles were on the road in Germany, including 48.54 million passenger cars, 4.78 million motor bikes, 3.55 million trucks and 80.23 thousand buses. The stock of BEV (cars) amounted to 618,460 (309,083 in 2020), that of HEV to 1,103,095 (724,228 in 2020). This corresponds to a year-on-year growth by a factor of 2 and of 1.5, respectively.

The proportion of passenger cars with alternative drive systems rose from 3.6% to 4.72 % (+31.0%) over the course of 2021. The share of cars with electric drive systems (including BEVs, PHEVs and FCEVs) doubled, from 1.2% to 2.44% (+103.5%). The fleet share of electric vehicles could have been even higher if it were not for the problem of dealers exporting used battery electric vehicles to other European countries after receiving the federal bonus and the minimum required holding period of 6 months[37]. While 355,961 battery electric vehicles were newly registered in 2021[35], the BEV fleet increased by only 309,377 vehicles (86.9%)[38].

*Total including ICEVs
** Including Mild-Hybrids

a Pedelecs with power assist up to 25 km/h
b UNECE categories L1 (Moped capable of driving up to 50 km/h with an engine less than 50cc)
c UNECE categories L2
d UNECE categories L3
e UNECE categories L4
f UNECE categories L5
g UNECE categories M1
h UNECE categories M2-M3
i UNECE categories N1

Source: Reference 35

Fleet Totals (as of December 31st 2021)

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike[a]	n.a.	n.a.	n.a.	n.a.	n.a.
Electric moped (<50 kmph)[b]	n.a.	n.a.	n.a.	n.a.	n.a.
Auto-rickshaw[c]	n.a.	n.a.	n.a.	n.a.	n.a.
Motorcycle[d]	18,840	618	7	0	4,780,854
Motorcycle with sidecar[e]	n.a.	n.a.	n.a.	n.a.	n.a.
Motorized tricycle[f]	n.a.	n.a.	n.a.	n.a.	n.a.
Passenger vehicles[g]	618,460	1,103,095**	565,956	1,211	48,540,878
Buses and Minibuses[h]	1,287	1,602	8	64	80,225
Light Commercial vehicles[i]	43,768	1,602	445	5	3,550,814
Medium and Heavy Weight Trucks[j]	n.a.	n.a.	n.a.	n.a.	n.a.

Total Sales 1st Jan 2020 to 31st Dec 2021

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike[a]	n.a.	n.a.	n.a.	n.a.	n.a.
Electric moped (<50 kmph)[b]	n.a.	n.a.	n.a.	n.a.	n.a.
Auto-rickshaw[c]	n.a.	n.a.	n.a.	n.a.	n.a.
Motorcycle[d]	4,096	n.a.	2	n.a.	200,231
Motorcycle with sidecar[e]	n.a.	n.a.	n.a.	n.a.	n.a.
Motorized tricycle[f]	n.a.	n.a.	n.a.	n.a.	n.a.
Passenger vehicles[g]	355,961	429,139*	325,449	464	2,622,132
Buses and Minibuses[h]	590	1,405	5	11	6,474
Light Commercial vehicles[i] Medium and Heavy Weight Trucks[j]	13,332	883	314	5	383,398

CHARGING INFRASTRUCTURE OR EVSE

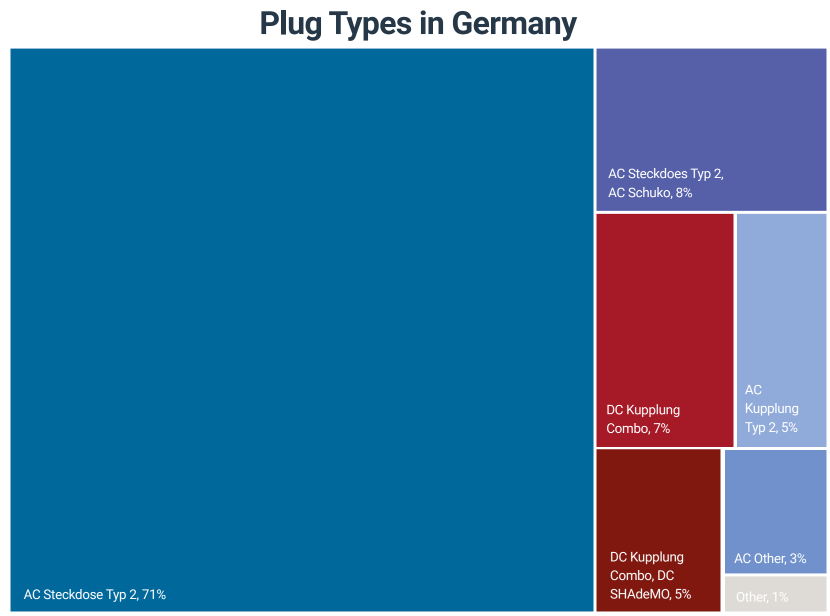
Since April 2017, the German Bundesnetzagentur has published an interactive overview map of charging points for electric vehicles. This map is updated monthly and contains the locations and technical characteristics of the loading points, which are registered as mandatory.

The map, published under the URL: http://www.bundesnetzagentur.de/ladesaeulenkarte shows the charging stations of all operators who have successfully completed the notification procedure of the Bundesnetzagentur and agreed to publication on the Internet. At the end of 2021, in Germany, there are 49,969 charging points, of which 41,812 are normal and 8,157 are fast charging points, at a total of 25,868 publicly accessible charging facilities. Given that at the beginning of 2020, there were around 19,688 charging facilities, the total number of charging facilities has increased by nearly 31% in 2021.

*As of December 31st 2021

Type of Public EVSE	Number of Charging Points*	Number of Locations*
AC Level 1 Chargers (≤3.7 kW)	379	268
AC Level 2 Chargers (>3.7 kW, ≤22 kW)	42787	22866
AC Fast Chargers (43 kW)	1349	1279
DC Fast Chargers (≤50 kW)	2105	1912
Tesla Superchargers (DC >120kW - 250kW)	649	443
Ultrafast-High power chargers (DC >50 kW and ≤350 kW)	2700	1792
Inductive Chargers (EM charging)	n.a.	n.a.

Figure 3: Plug types in German EVSE, 1.01.2022 (based on data from Bundesnetzagentur)



GERMANY: A CONTINUOUS INCREASE IN H2 FILLING STATIONS

As of 9 March, 2022, there were 91 hydrogen filling stations in operation in Germany, with a further 11 currently being commissioned and in trial operation[40]. A total of 142 hydrogen filling stations have been put to operation worldwide in 2021. 37 were opened in Europe, 89 in Asia and 13 in North America. Korea showed a particular dynamic expansion as they extended their H2 network by 26 filling stations in 2020 and another 36 in 2021. In contrast to most other hydrogen stations, the 105 Chinese hydrogen stations are almost exclusively used to refuel bus and truck fleets. In North America, the hydrogen network concentrates on California, with nearly 70% of the overall 86 hydrogen stations. At the end of 2021, a total of 685 hydrogen filling stations were in operation worldwide[41].

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Ireland

MAJOR DEVELOPMENTS IN 2021

Demand for EVs in Ireland grew dramatically in 2021. Whereas the previous year saw EV registrations grow by 39%, year on year growth in 2021 was 134%, as consumers began to embrace the need for change away from internal combustion engine (ICE) vehicles. Vehicle Registration Tax (VRT) was reduced from 14% to 7% for zero CO2 emission vehicles and in parallel NOx taxation, which provides increasing penalties for diesel fuelled vehicles in particular, was increased. The Climate Action Plan was released, which aims to deliver 845,000 EVs on Ireland's road by 2030 and to effectively prohibit the sale of petrol and diesel cars after that date.

Procurement of PHEV & BEV Bus Fleets Commences

100 double-decker PHEV buses were ordered by the National Transport Authority (NTA) in 2020, and a further 180 were ordered in 2021. They began entering service in 2021 with bus operators Dublin Bus and Bus Éireann. The buses are Enviro 400ER, which are manufactured by Alexander Dennis Limited (ADL) and utilise BAE Systems' Series-ER hybrid system that incorporates a 32kWh lithium-ion battery energy storage system that can be charged externally via a plug-in connection. They are capable of running within a zero-tailpipe emission mode for a distance of at least two and a half kilometres and will reduce greenhouse gas emissions by at least 30%.

Figure: Arrival of 32kWh PHEV Double Decker Buses in Ireland

With respect to BEV bus procurement, NTA signed a framework agreement with ADL for the delivery of up to 200 BEV single deck long length urban buses. The first batch of 45 buses are expected to be delivered in 2022 and are expected to be operated on routes in Athlone and the Dublin Metropolitan Area.

The bus chosen is the Enviro 200EV, which typically uses a 348kWh lithium iron phosphate battery, offering an expected range on a single charge of 260km. The bus will be produced via a partnership between ADL and BYD Company Limited. BYD will supply the chassis of the bus including the traction battery pack and powertrain, while ADL will fit the coach body and supply it ready for the Irish market.

HEVs, PHEVs, and EVs on the Road

In 2021, the main EV vehicle grant subsidy was reduced for PHEV from €5,000 to €2,500 at the mid-year point. In addition, the scheme was further refined to only allow grant support for PHEVs with a minimum all electric range of 50km and tail pipe emission not exceeding 50g/km. Additionally, only vehicles with a list price not exceeding €60,000 (either BEV or PHEV) were allowed support under the scheme. This scheme is administered by the Sustainable Energy Authority of Ireland (SEAI).

VRT relief ended in December 2020 for HEV and PHEV but was continued for BEVs only. While there is no grant subsidy for electric motorcycles, they are exempt from paying VRT.

BEVs passenger cars are exempt from Benefit in Kind tax for the first €50,000 value of the car on an Original Market Value. Road toll discounts were also continued for EVs in 2021.

Grants for taxi drivers looking to scrap an older ICE vehicle in favour of a BEV have been increased significantly in 2021. Those scrapping older, more polluting, or high mileage taxi vehicles are eligible for grants of up to €20,000 when purchasing a new BEV or €25,000 for a wheelchair accessible BEV.

Finally, grant support is provided towards the purchase of Alternatively Fuelled Heavy Duty Vehicles, including BEV/PHEV/FCEVs. Grant levels of up to 60% of the price differential with respect to an equivalent diesel truck are provided, with variations depending on the size of the business applying for support.

Source: National Vehicle & Driver File, Department of Transport, Jan 2022

*Total including ICEVs
** Passenger Vehicles include Taxis and Hackney category vehicles
*** Only Goods Vehicle category was available in time, which includes Light/Medium/Heavy vehicles all together

Fleet Totals as of December 31st 2021

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	n.a.	n.a.	n.a.	n.a.	n.a.
Electric moped (<50 kmph)	n.a.	n.a.	n.a.	n.a.	n.a.
Auto-rickshaw	n.a.	n.a.	n.a.	n.a.	n.a.
Motorcycle	131	12	24	0	46,636
Motorcycle with sidecar	n.a.	n.a.	n.a.	n.a.	n.a.
Motorized tricycle	n.a.	n.a.	n.a.	n.a.	n.a.
Passenger vehicles**	21,279	85,072	23,697	0	2,250,257
Buses and Minibuses	1	138	100	2	11,090
Light Commercial vehicles***	1,770	273	208	1	385,099
Medium and Heavy Weight Trucks	n.a.	n.a	n.a	n.a	n.a

Total Sales 1st Jan 2021 to 31st Dec 2021

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	n.a.	n.a.	n.a.	n.a.	n.a.
Electric moped (<50 kmph)	n.a.	n.a.	n.a.	n.a.	n.a.
Auto-rickshaw	n.a.	n.a.	n.a.	n.a.	n.a.
Motorcycle					
Motorcycle with sidecar	n.a.	n.a.	n.a.	n.a.	n.a.
Motorized tricycle	n.a.	n.a.	n.a.	n.a.	n.a.
Passenger vehicles**	8,558	18,184	7,873	0	104,610
Buses and Minibuses	n.a.	n.a.	c. 100	n.a.	n.a.
Light Commercial vehicles***	600	190	20	0	28,446
Medium and Heavy Weight Trucks	n.a.	n.a	n.a	n.a	n.a

CHARGING INFRASTRUCTURE OR EVSE

ESB Ecars deployed their first fast charger hubs, comprising sites with up to eight charging units, each capable of supplying up to 350kW. This deployment was supported with funds from the Climate Action Fund.

SEAI continues to operate the EV Home Charger grant scheme, which provides grants of €600 per charger installation in a house with off-street parking adjacent to the house. It is available to purchasers of new and second-hand EVs.

Notes: Charge points operators include ESB Ecars, Tesla, Ionity and Easygo. Charger locations selected include on-street locations, public car parks, shopping centres, refuelling stations, civic buildings, and hotels, but exclude private or commercial location car parks.

* As of December 31st 2021

Type of Public EVSE	Number of Charging Points*	Number of Locations*
AC Level 1 Chargers (≤3.7 kW)	0	0
AC Level 2 Chargers (>3.7 kW, ≤22 kW)	937	450
AC Fast Chargers (43 kW)	65	65
DC Fast Chargers (≤50 kW)	124	120
Tesla Superchargers (DC >120kW - 250kW)	36	6
Ultrafast-High power chargers (DC >50 kW and ≤350 kW)	38	14
Inductive Chargers (EM charging)	0	0

EV DEMONSTRATION PROJECTS

Ireland's national postal delivery service, An Post, have converted over 30% of their 4,000 vehicle fleet to EVs and are committed to converting 50% by 2022 and thereafter being fully electric by 2030. Within that fleet, it operates electric trikes, delivery vans and other heavier vehicles all the way up to HGVs. The company joined the EV100 global initiative, which comprises leading international businesses who are dedicated to accelerating the move towards EVs worldwide. An Post are the first postal service in the world to attain zero carbon emission delivery status in a capital city.

Figure: An Post – Dublin is the world's first Zero Emission Postal Capital

OUTLOOK

With the majority of EV charging typically done at home, Ireland has been working to ensure that all domestic residents have access to on-site charging. Three residential charging scenarios are identified, including private dwellings with off-street parking, dwellings relying on public on-street parking, and finally apartment dwellings which use car parks. Grant programmes are in place for the first two scenarios, but a programme is about to be launched in Q1 of 2022, which will provide grant support to residents of apartment blocks and other multi-unit developments with shared parking areas.

SEAI is also engaged in a number of activities in 2022, which will provide valuable data and stimulation to the EV market. A "Mystery Shopper" study is being prepared which involves performing a number of attempted EV purchases via a number of randomly selected vehicle Dealerships. The study is being used to gauge the preparedness and readiness of Dealers to encourage an undecided vehicle purchaser to choose an EV. The critical role of the Dealer in promoting the uptake of EVs is being recognized by the creation of a national EV Dealer Award in 2022 by SEAI.

In order to promote adoption of EVs within the business community, a company trial of EVs is being created. Fifty cars and vans will be leased to a variety of companies and charging infrastructure will be installed. These will inform case studies, which will be used to inform other businesses who wish to change out their fleet and switch to EVs.

EV chip shortages will continue to cause supply issues in 2022. Brexit may cause further concern for Ireland, which, like the UK, is reliant on right-hand drive vehicles. EU Vehicle CO2 targets will only now apply to vehicles sold within the EU, which now excludes the UK. One long-term concern is whether this will affect the variety and number of right-hand drive EVs available to Ireland, as European manufacturers may seek to channel their constrained supply of EVs to European countries only. A further issue unique to Ireland related to Brexit is the import of second-hand cars. Brexit will now impose 23% VAT costs on all vehicles imported second-hand from Britain, which has traditionally been a source for ~30-40% of all vehicle registrations in Ireland. This number shows signs of reducing, but COVID effects remain to be separated before the full impact of Brexit on second-hand imports to Ireland can be gauged.

Italy

MAJOR DEVELOPMENTS IN 2021

New policies, legislation, incentives, funding, and taxation

In Italy, the “Budget” Law 2019[1] introduced a bonus for purchasing new vehicles. From 1 March 2019 to 31 December 2021, everyone who is willing to purchase (even with a lease) and register a new passenger car (UNECE M1 category) in Italy with CO2 emissions below a given threshold value will be provided with a bonus (in the form of a discount) depending on the amount of CO2 emissions per km.

In 2020, with the “Recovery” Law-Decree[2] and the “August” Law-Decree[3] which establish urgent measures on health, job, economy and policies related to the epidemiological emergency due to COVID-19, funds for purchasing EVs were increased together with the number of beneficiaries. Table 1 shows the policy framework for electric mobility in 2021 related to these measures.

Table 1: Direct incentives for purchasing new passenger cars in 2021

CO2 Emissions (g/km)	Bonus with scrapping (Euros)	Bonus w/out scrapping (Euros)
00 ÷ 20	10,000	6,000
21 ÷ 60	6,500	3,500
61 ÷ 90	3,750	2,000
91 ÷ 110	3,500	1,750

On the other hand, anyone who purchases (even with a lease) and registers a new passenger car in Italy exceeding the threshold value of 160 gCO2 per km, will be charged with a tax depending on the amount of CO2 emissions per km, as reported in Table 2.

Table 2: Taxation for purchasing new passenger cars (2021)

CO2 Emissions (g/km)	Tax (Euros)
161 ÷ 175	1,100
176 ÷ 200	1,600
201 ÷ 250	2,000
> 250	2,500

The purchase of used vehicles is also subjected to an incentive[4]: the "eco-bonus" concerns M1 vehicles (common passenger cars) of at least Euro 6 Class and CO2 emissions between 0 and 160 g/km, purchased from 25th July 2021 and with an average market price not exceeding 25,000 EUR. Only private individuals (no companies) can request this incentive, and the purchase of used cars under a lease is not allowed. Vehicles having already used the state incentives at the time of first registration are also excluded from the contribution. The awarding of the incentive is linked to the simultaneous scrapping of a vehicle of the same category as the one purchased, registered for at least 10 years, and registered for no less than 12 months to the buyer or a cohabiting family member. The contribution differs according to the emission range of the used vehicle that is purchased, as shown in Table 3.

Table 3: Incentives for purchasing used passenger cars (2021)

CO2 Emissions (g/km)	Tax (Euros)
0 ÷ 60	2,000
61 ÷ 90	1,000
91 ÷ 160	750
> 250	2,500

Indirect incentives are mainly released at regional level. The reduction of the annual registration tax is the most used form of indirect incentive. Usually, electric vehicles are exempt from the annual registration tax for a time period of five years starting from the date of the first registration. After this initial five years time, they benefit from a 75% reduction of the value that would be applied to the equivalent petrol vehicles of the same power. On the other hand, hybrid vehicles are exempt from the yearly registration tax for a time period from zero to five (usually three) years from the date of the first registration. After this period, the full conventional tax will be applied. Figure 1 shows the details of the regional policy on the exemption from the annual registration tax, with the exception of some regions.

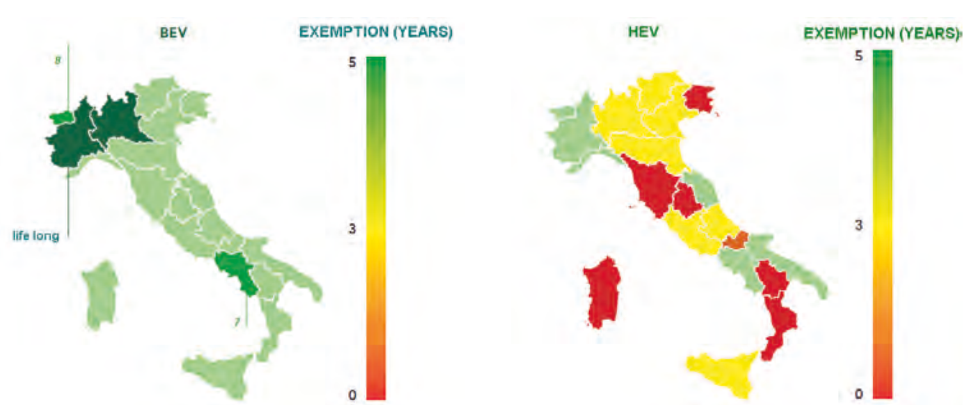

Figure 1: Regional policy on registration tax exemption

Image courtesy of Politecnico di Milano, Smart Mobility Report 2021

In many municipalities, electric vehicles have free access to limited traffic zones and free parking in reserved areas.

Some municipalities are gradually introducing or increasing banning to conventional vehicles.

Regarding the incentives on private charging points, there are two options:

- According to the “Balance” Law 2019[1], taxpayers are granted a tax deduction (to be distributed in 10 years) for costs incurred from 1st March 2019 to 31st December 2021 regarding the purchase and installation of EV charging infrastructures. This tax deduction is in the amount of 50% of the costs on a total amount not exceeding 3,000 EUR.

- Under the “Recovery” Law-Decree[2], taxpayers are granted a tax deduction (to be distributed in 5 years) for costs incurred from 1st July 2020 to 31st December 2021 regarding the purchase and installation of EV charging infrastructures when these supply equipments are in combination with renovation measures aimed at increasing the energy efficiency in buildings. For each taxpayer, this tax deduction is 110% of the total cost, not exceeding 3,000 EUR, and other restrictions depending on the type of building unit.

In both cases:

- The charging infrastructures must have one or more not publicly accessible standard* charging points.

- Initial costs for demanding additional power up to 7 kW are also included.

- Instead of the fiscal deduction, it is possible to choose the discount in invoice and/or to transfer the tax credit.

*Standard charging point means a charging point allowing for a transfer of electricity to an electric vehicle with a power less than or equal to 22 kW. Devices with a power less than or equal to 3,7 kW, installed in private households or for which the primary purpose is not to recharge electric vehicles, and that are not accessible to the public, are not considered standard charging points.

For further details on the conditions for eligibility, please directly refer to the sources listed in the references at the end of this document.

HEVS, PHEVS, AND EVS ON THE ROAD

The number of passenger cars registered in the year 2021 does not exceed 1.5 million, but stops at 1.46 million vehicles, with a drop compared to 2019 in which more than 1.9 million vehicles were registered. However, we had observed a very slight recovery in 2020. This is a sign that the market has not yet fully recovered from the effects of the pandemic period.

*Total including ICEVs

Sources:
a ANCMA
b ANFIA
c FederAuto
d EAFO
e Motus-E
f ACI 01/01/2021
g ENEA

Fleet Totals (as of December 31st 2021)

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	1,300,000[a]	n.a.	n.a.	n.a.	50,000,000[a]
Electric moped (<50 kmph)	n.a.	n.a.	n.a.	n.a.	1,300,000[a]
Auto-rickshaw	n.a.	n.a.	n.a.	n.a.	n.a.
Motorcycle	n.a.	n.a.	n.a.	n.a.	6,800,000[a]
Motorcycle with sidecar	n.a.	n.a.	n.a.	n.a.	n.a.
Motorized tricycle	n.a.	n.a.	n.a.	n.a.	n.a.
Passenger vehicles	122,138[e]	964,918[g]	113,538[e]	45[d]	39,717,874[f]
Buses and Minibuses	669[d]	n.a.	n.a.	13[d]	99,883[f]
Light Commercial vehicles	9,441[d]	5,816[g]	489[d]	n.a.	4,221,718[f]
Medium and Heavy Weight Trucks	47[d]	3[g]	n.a.	n.a.	764,737[f]

In 2021, thanks to the incentives, the new registrations of electrically rechargeable passenger cars recorded a growth of 130% compared to 2020, corresponding to 137,745 vehicles registered and a share of 9.45% on the total market. In 2021, BEV passenger cars, with 67,273 units registered, doubled the number of registrations (+ 107% in 2021, compared to 32,485 units registered in 2020). On the other hand, PHEVs, with 70,472 units registered, reached a growth of +157.13 %, compared to 27,407 units in 2020. Therefore, in 2021, registrations of electrically rechargeable passenger cars were distributed equally between BEV (49%) and PHEV (51%).

Total Sales 1st Jan 2021 to 31st Dec 2021

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	320,000[a]	n.a.	n.a.	n.a.	1,850,000[a]
Electric moped (<50 kmph)	3,900[a]	n.a.	n.a.	n.a.	18,835[a]
Auto-rickshaw	n.a.	n.a.	n.a.	n.a.	n.a.
Motorcycle	6,906[a]	n.a.	n.a.	n.a.	270,232[a]
Motorcycle with sidecar	n.a.	n.a.	n.a.	n.a.	n.a.
Motorized tricycle	n.a.	n.a.	n.a.	n.a.	n.a.
Passenger vehicles	67,273[b]	422,190[b]	70,472[b]	10[b]	1,457,952[c]
Buses and Minibuses	84[d]	n.a.	n.a.	n.a.	3,487[b]
Light Commercial vehicles	3,129[d]	n.a.	382[d]	n.a.	183,093[b]
Medium and Heavy Weight Trucks	8[d]	n.a.	n.a.	n.a.	24,776[b]

CHARGING INFRASTRUCTURE OR EVSE

In 2021, despite the Covid-19 pandemic and its long-term effects still generating slowdowns in various areas related to mobility, there is also a growing trend in the charging infrastructure for electric vehicles, confirming a strong interest by both users and operators in the sector. As of December 31st, 2021, 26,024* recharging points were installed in Italy (not including the charging devices that can be used only by the staff of a company or only by customers of a restaurant, hotel, or shop, as well as infrastructures reserved exclusively for certain brands of electric vehicles), and 13,223 infrastructures (stations or columns) in 10,503 locations accessible to the public. 79% of the infrastructures are located on public land (e.g., road), while the remaining 21% on private land for public use (e.g., supermarkets or shopping centres).

* This amount includes also 292 "not well defined" charging points

Type of Public EVSE	Number of Charging Points**	Number of Locations**
AC Level 1 Chargers (≤3.7 kW)	4,096[b]	10,503[b]
AC Level 2 Chargers (>3.7 kW, ≤22 kW)	19,165[b]	
AC Fast Chargers (43 kW)	922[b]	
DC Fast Chargers (≤50 kW)	914[b]	
Tesla Superchargers (DC >120kW - 250kW)	355[a]	
Ultrafast-High power chargers (DC >50 kW and ≤350 kW)	635[b]	
Inductive Chargers (EM charging)	n.a	n.a

**As of December 31st 2021

Source:
a EAFO
b Motus-E

Today, about 57% of the recharging points are distributed in Northern Italy, about 23% in the Centre while only 20% in the South and the Islands[5]. Despite the very significant differences between the different regions in terms of installed charging points, it is important to underline that the Italian recharging network is spreading widely. Indeed, as shown in Figure 2, the ratio between the number of charging infrastructures and the number of electrically rechargeable vehicles in Italy is above the European average, demonstrating that the long-term goal of achieving a capillary of the recharging service is being pursued.

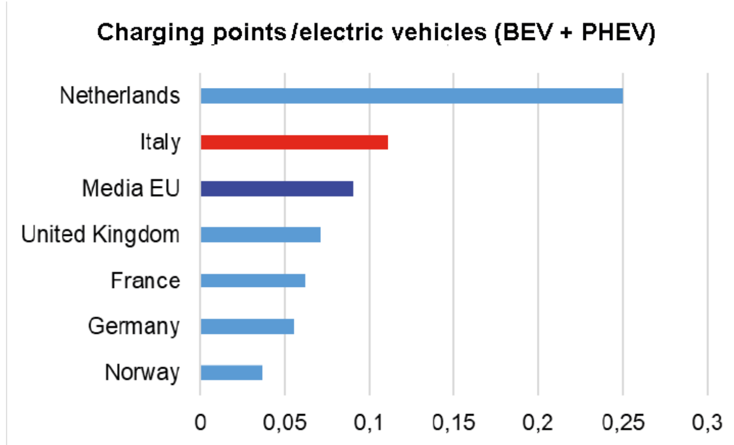

Figure 2: Relation between charging points and electric vehicles. Image courtesy of Motus-E

With regard of the charging infrastructures on the motorway network, Italy is still lagging behind: in fact, today there are only 1.2 fast or ultra-fast charging points per 100 km of the motorway network (not considering the charging stations located nearby the access-exit points of the motorways and installed on extra-urban roads). At the date, 118 public charging points have been installed, 78% of these charge at powers above 43 kW (DC), while the remaining 22% have a charging power lower than or equal to 43 kW (AC). It should be emphasized that about half (48%) of the recharging points have a power equal to or greater than 150 kW.

To facilitate extra-urban travels with electric vehicles, a more widespread diffusion of recharging points, in particular those with high power, would be advisable. The Autostrade Group's Plan foresees the construction of a network of high-power charging stations (300 kW) in 100 service areas: two are already active today[6]. From a regulatory and policy point of view, the main issues addressed in 2021 regarding the public charging infrastructure are: the new European Regulation Proposal for Alternative Fuel Infrastructures (AFIR), the Recovery and Resilience National Plan (RRNP) and the Simplification Decree.

AFIR will replace the Directive for Alternative Fuel Infrastructures with the substantial difference that it will be no longer a directive, but a regulation, and therefore could introduce mandatory targets. The main aim is to ensure the minimum infrastructure in order to support the growth of alternative fuel vehicles in all Member States.

The latest version of the RRNP promotes the development of electric mobility with 750 million EUR for the installation of about 21,400 fast and ultra-fast charging points by the end of 2025. In detail, within Mission 2 (Green Revolution and Ecological Transition) of Component 2 (Renewable energy, hydrogen, network, and sustainable mobility) of the RRNP, an investment is planned for the development of electric charging infrastructures to install 7,500 fast charging points in suburban areas and 13,755 in urban centres, as well as 100 experimental charging stations with energy storage technologies [7].

The Simplification Decree introduces simplifications on authorization issues for the installation of public access charging infrastructures[3].

EV DEMONSTRATION PROJECTS

In 2021, the main national research institutions (National Research Council of Italy CNR, Italian National Agency on New Technologies, Energy and Sustainable Economic Development ENEA, and Research on Energy System RSE) continued their R&I activities and demonstration projects on topics relating to electro-mobility:

- energy storage: materials, components and systems, test procedures (especially fast charging, ageing and stress tests) for batteries, supercapacitors, fuel cells, hybrid configurations, flywheels;
- vehicles: propulsion system, drive cycles;
- e-mobility: charging infrastructure and services, smart DC micro-grids, scenarios and tools for e-mobility and its integration and interaction with the electric system, use of renewable energy sources, local public transport, smart cities.

In addition, many other projects and demonstrators of innovative technologies are going to be developed in Italy under the initiative of industrial stakeholders.
A group of important international industrial companies supported by prestigious universities and institutions (A35 Brebemi-Aleatica motorway, ABB, Electreon, FIAMM Energy Technology, IVECO, IVECO Bus, Mapei, Pizzarotti, Politecnico di Milano, Prysmian, Stellantis, TIM, Roma Tre University, and the University of Parma) work together in the project "Arena del Futuro"[8] to demonstrate effectiveness and efficiency of technologies to power electric cars, buses, and commercial vehicles using contactless dynamic inductive charging.

Figure 3: The ring Arena del Futuro. Image courtesy of Stellantis.

The project includes:

- construction of a 1,050-metre asphalt ring powered by 1MW of electrical power, called the "Arena del Futuro", Figure 3, located in a private area of the A35 motorway near the Chiari Ovest exit;
- applying "Dynamic Wireless Power Transfer" technology to various ranges of electric vehicles in a static and dynamic environment;
- advanced connectivity through 5G and IoT (Internet of Things) technologies to ensure maximum road safety and optimize the productivity of commercial vehicles;
- optimizing the road surface in order to make it more durable and to not impact the efficiency of the inductive charge.

FCA, the main car manufacturer in Italy, Engie eps, a leader company in energy storage and e-mobility, and Terna, the Italian Transmission System Operator, join their efforts in the Vehicle-to-Grid (V2G) pilot project at the Mirafiori logistics hub[9].

Phase 1 of the plant's construction consisted of the installation of 32 V2G columns capable of connecting 64 vehicles, aimed at piloting the technology and managing the logistics of the storage area. The V2G project will be extended to interconnect up to 700 electric vehicles, making it the largest facility of its kind ever built in the world. Phase 2 will be mainly dedicated to cost-effectiveness: the objectives will be to provide services to Terna power grid and to ensure a positive economic result for the economic operators.

To cover the parking spaces for the cars connected to the V2G, ENGIE Italia is a partner in the construction of an enormous roof consisting of around 12,000 solar panels, which will supply the production and logistics facilities with 'green' energy. The plant will be able to produce over 6,500 MWh of energy every year, resulting in the offsetting of more than 2,100 tons of CO2 emissions per year. The project therefore represents a significant contribution to decarbonization in the industrial sector.

Stellantis, together with partners Nhoa and Free2Move eSolutions and with the collaboration of the Piedmont Region, has launched the Atlante project[10] which involves the development of the first fast charging network fully integrated with the electricity network (vehicle-grid-integrated, VGI), energy renewable and storage systems. The project will be initially developed in Southern Europe (Italy, France, Spain, and Portugal) and will be an open charging network and also the preferred fast charging network for Stellantis customers.

The Atlante Project responds to the provisions of the "Fit for 55" package - adopted by the European Commission in mid-July 2021 - whose objective, among others, is to install electric charging points at regular intervals of 60 kilometers. The power of the fast charging stations will vary from a minimum of 100 kW to a maximum of 175 kW.

Piaggio Group have signed the agreement for the creation of the Swappable Batteries Motorcycle Consortium together with Honda Motor, KTM, and Yamaha Motor for motorcycles and light electric vehicles[11]. The availability of commonly developed swappable battery systems is the key to the development of low-voltage electromobility: the aim of the Consortium is to find solutions to the concerns that customers may have regarding the future of electromobility, such as the range, the charging time and infrastructure, and costs. This will be achieved in accordance with four primary goals:

- develop common technical specifications of the swappable battery systems;
- confirm common usage of the battery systems;
- make, and promote, the Consortium's common specifications a standard within European and International standardization bodies;
- expand the use of the Consortium's common specifications to global level.

By working closely with interested stakeholders and national, European, and international standardization bodies, the founding members of the Consortium will be involved in the creation of international technical standards and engaging the decision makers for the development and deployment of charging infrastructure to promote the increase of light electric vehicles.

Italy, through Piaggio Group, has recently joined China and Germany in the IEA-HEV-TCP's Task 48 "Battery Swapping" especially focused on creating stronger infrastructure for battery swapping technology and sharing of information.

Finally, in January 2021, the European Commission has approved, under EU State Aid rules, a second Important Project of Common European Interest ("IPCEI") to support research and innovation in the battery value chain[12]. The project, called "European Battery Innovation - EuBatIn", was jointly prepared and notified by Austria, Belgium, Croatia, Finland, France, Germany, Greece, Italy, Poland, Slovakia, Spain, and Sweden.

The twelve Member States will provide up to 2.9 billion EUR in funding in the coming years. The public funding is expected to unlock an additional 9 billion EUR in private investments, i.e., more than three times the public support. The project involves 42 companies (see details in Figure 4); more specifically, 14 of these 42 direct participants are Italian (12 enterprises and two research organizations). Italy has sought approval to grant up to approximately 600 million EUR.

Figure 4: Participants in the EuBatIn Project. Image courtesy of European Commission.

The project complements the first IPCEI in the battery value chain that the European Commission approved in December 2019. The project will cover the entire battery value chain, from extraction of raw materials, design, and manufacturing of battery cells and packs, to finally the recycling and disposal in a circular economy, with a strong focus on sustainability.

OUTLOOK

In October 2021, the Italian Polytechnic Institute in Milano published the “Smart Mobility Report”[13] that, beside reporting a detailed analysis of technologies, regulations, and current car market, presented forecasts from three market scenarios that can be summarized as follows:

- “Business As Usual” scenario: this scenario foresees an adoption of electric vehicles that does not reach 4 million vehicles in 2030;
- “Policy Driven” scenario: in this scenario, electric vehicles reach 6 million in 2030;
- “Decarbonization” scenario: in this scenario, electric vehicles will reach about 8 million in 2030.

It should be noted that the value foreseen by the “Policy Driven” scenario in 2030 is equal to that one envisaged by the Integrated Energy and Climate National Plan[14]. These forecasts are shown in Figure 5 together with the ones on sales.

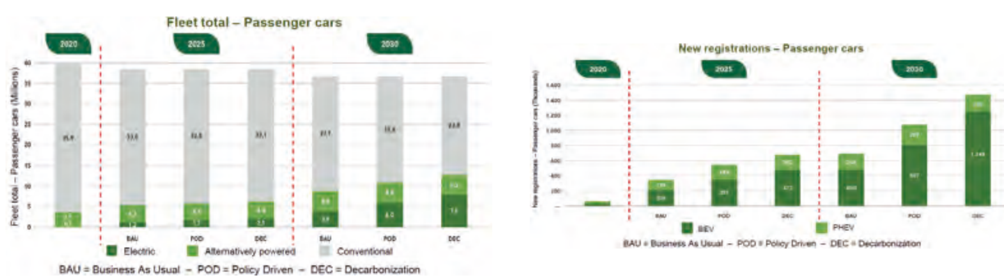

Figure 5: Forecast on fleet and new registration of passenger cars. Image courtesy of Politecnico di Milano, Smart Mobility Report 2021.

With regard to publicly accessible charging points for electric vehicles by 2030, as shown in Figure 6, we go from a minimum of 57,000 in the "Business as Usual" scenario, to a maximum of 83,000 in the “Decarbonization” scenario, passing by approximately 67,000 in the “Policy Driven” scenario. With regard to private charging points for electric vehicles, the "Business as Usual" scenario foresees a diffusion that goes a little bit beyond 2 million units by 2030, while in the “Policy Driven” scenario, the private charging points go a little bit more than 3 million and, in the “Decarbonization” scenario, private charging points reach 4 million units.

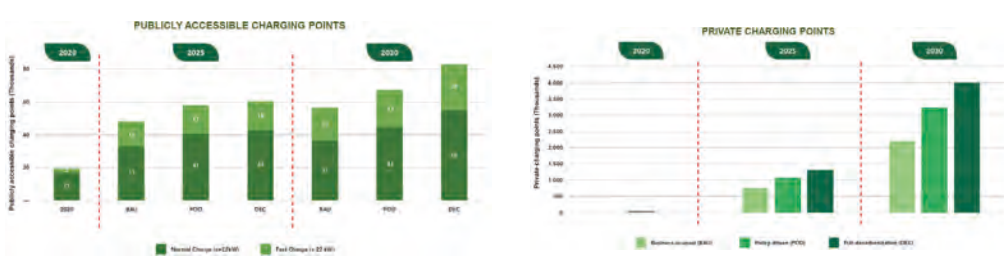

Figure 6: Forecast on charging points. Image courtesy of Politecnico di Milano, Smart Mobility Report 2021

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The Netherlands

MAJOR DEVELOPMENTS IN 2021

Supported by the national climate policy, the Netherlands has ambitions to improve the sustainability of mobility. By 2030, it is the ambition that all new passenger vehicles in the Netherlands must be zero-emission. All vehicles will have to make the best possible use of renewable energy sources, such as wind and solar.

The National Charging Infrastructure Agenda, part of the National Climate Agreement, was in full swing in 2021. It is a multi-annual and multi-stakeholder agenda to make sure that charging infrastructure is not a barrier for the electrification of all vehicle types. Working groups addressing the realization process, open protocols and markets, smart charging, safety and cyber security, and logistics and construction, make sure all these subjects are under attention.

The Formula E-Team is the Dutch public-private platform to promote e-mobility and accelerate the transition to electric vehicles, collaborating with the government. The aim is to meet the climate targets and, in addition, to take advantage of the associated economic opportunities.

Despite the Covid19 pandemic, the number of electric passenger cars increased considerably again in 2021, accounting for a 30% sales share in total passenger car sales. The available purchase subsidy for both new and used cars was depleted quickly. Regular public chargers grew by 30% and fast charging locations increased by 35%, with more and more chargers over 100 kW.

Policy Developments

The new cabinet in the Netherlands will reinforce the efforts towards counteracting climate change and supporting the energy transition. Climate goals will be tightened, and a special climate and transition financial fund of 35 million EUR has been announced. As far as mobility is concerned, one of the striking goals is that this cabinet will start preparing a system for paying according to use (instead of the current car tax system), expected to be introduced by 2030.

In February 2021, municipalities, transport organisations and the Ministry of Infrastructure and Water Management together signed an Implementation Agenda for City Logistics. They made arrangements on the zero-emission supplying of cities. As of 2025, cities can implement a zero-emission zone for commercial vehicles. Already, 26 municipalities have announced a zero-emission zone. A roadmap for logistical charging was developed to make sure that all electric logistic vehicles can charge efficiently. Also, a knowledge and action agenda was drawn up for logistical charging.

At COP 26 in Glasgow in November 2021, 15 countries and several transport organisations spread across four continents signed an agreement that aims for all new heavy goods vehicles and buses in their countries to be zero-emission from 2040. The agreement is an initiative of the Netherlands. Because the lifespan of heavy-duty vehicles is generally around 10 years, the agreement is a positive step towards emission-free fleets around the world by 2050.

The Netherlands is actively working on roaming across borders and price transparency for EV drivers. From 1st July 2021, CPOs are obliged to publicly share information on the availability and ad hoc prices of (semi) public chargers, so dynamic information can be gathered. To promote cross-border electric driving and charging, Belgium, Luxemburg, and the Netherlands have established the joint service IDRO (Benelux ID Registration Organisation). IDRO is to issue unique ID codes for charging station operators and mobility service providers in the Benelux countries and subsequently manage them. Based on these codes, operators and providers should be able to determine which card was used when for a specific charging process, in order to send the corresponding invoice to the right customer.

Financial and Fiscal Incentives

One of the drivers behind the increase of electric vehicles in the Netherlands is fiscal and financial stimulation. The focus is on stimulating zero-emission vehicles. Tax measures for plug-in hybrid vehicles will gradually be reduced to the same level as conventional cars. Table 1 provides an overview of the incentives that were in place in 2021, also including purchase grants for cars and vans.

Table 1: Fiscal and financial incentives in the Netherlands 2021

Policy Measure	Details
Registration tax	Zero emission cars are exempt from paying registration tax. For conventional cars, the system is progressive, with a starting tariff and 5 levels of CO2 emissions, with incremental amounts of registration tax. Plug-in hybrid cars get a discount compared to conventional cars, they do not have a starting tariff and have 3 levels of CO2 emissions with lower amounts of registration tax. Diesels have a surcharge.
Road tax (circulation tax)	Zero-emission cars are exempt from paying road tax. Plug-in hybrid cars < 51 gr CO2/km pay half the tariff (up to 2024). For conventional cars, this tax is € 400 to € 1.200 (depending on fuel, weight, and address).
Surcharge on income tax for the private use of company cars	In the Netherlands, income tax has to be paid on the private use of a company car. This is implemented by imposing a surcharge of 12% or 22% of the catalogue value on the taxable income. For BEV cars with a purchase price < €40,000, this percentage is 12%. For the part > €40,000, and for other cars, including plug-in hybrid cars, it is 22%. For FCEV and solar cars (> 1 Kilowatt-peak), the surcharge is 12% over the total purchase price, so no limitations.
Tax deductible investments	The Netherlands has a system of facilitating investments in clean technology, by making these investments partially deductible from corporate and income taxes. Zero emission and plug-in hybrid cars < 31 gr CO2/km (no diesel engine) are on the list of deductible investments, as are the accompanying charging points.

Policy Measure	Details
Purchase grant electric passenger cars	Private persons can get a purchase subsidy of 4,000 EUR for a new electric car and 2,000 EUR for a used electric car. The subsidy is applicable to BEVs with an action radius of at least 120 km, with a catalogue value between 12,000 EUR and 45,000 EUR and not to converted cars.
Purchase grant emission-free delivery vans	Companies can get a 10% subsidy of the net catalogue value for new emission-free N1 and N2 vehicles with a maximum weight of 4,250 kg. The maximum subsidy amount per van is 5,000 EUR. SMEs can get a 12% subsidy.

The energy tax for electricity for public chargers is decreased. It contributes to the willingness of companies to invest in public charging infrastructure.

Next to these national incentives, various municipalities and regions offer different grants and schemes for electric vehicles. Some examples:

- Rotterdam: subsidy for efficient and clean construction site logistics;
- Amsterdam: subsidy for electric commercial vehicles and taxis;
- Gelderland and Overijssel province: subsidy for electric vans.

Market Developments

In the coming years, Vattenfall will place 8,000 new charging points in the southern provinces of Noord-Brabant and Limburg. Of these, 4,500 will be placed pro-actively, so before inhabitants request them. Best locations will be decided upon by using data-driven prognose maps and plan maps.

In 2021, municipalities in the provinces of North-Holland, Utrecht and Flevoland did not have to contribute financially anymore for the installation of public charging poles. The growing number of electric vehicles in these regions results in a conclusive business case for the CPOs. Municipalities determine locations, the CPO installs at own costs.

More than 25% of buses used for public transport are full electric. Already 23 of the 31 concessions in the Netherlands have emission free buses, both in and outside cities. This success is due to a mix of collaboration, clear goals (zero emission public transport by 2030) and knowledge exchanges.

Solar Team Eindhoven presented the world's first solar powered mobile home called Stella Vita. The vehicle generates enough solar energy to live and drive on. Through solar panels on the roof, it is independent of charging stations. In addition, extra solar panels fold out when the roof is raised, doubling the solar surface to as much as 17.5 square meters. By using energy efficiently, Stella Vita can travel up to 730 km on a sunny day.

Figure 1: Stella Vita solar camper. Photo courtesy: STE/ Bart van Overbeeke

There were several announcements of zero emission special vehicles, like an asphalt spreader (UMS/Dynapac), an electric truck with squeezer installation (Dura Vermeer) and an electric crawler crane (VolkerWessels). Construction machines are a bottleneck for further building projects as a result of the nitrogen emissions. Electrification at building sites is an important step forward for local air quality and reduces noise and smell for people living in the vicinity.

Knowledge, Innovation and Research

The Dutch EV sector provides ever increasing employment and, looking at the large growth in electric driving, this will only continue to increase in the coming years. Netherlands Enterprise Agency conducts biannual research to monitor economic indicators. Research published in 2021 showed that the number of jobs that are directly related to EV has increased to 6,860 full-time equivalents (FTE). EV related turnover has increased to over 4 billion EUR in 2020.

The National Knowledge Platform on Charging Infrastructure (NKL) conducted a benchmark on price transparency in the Netherlands. Price transparency is one of the starting points of the National Charging Infrastructure Agenda. In 81% of the 1,200 charging sessions that were analyzed, the price was known beforehand and matched the tariffs that were billed. Price transparency during and after charging can be improved, though. The research also found that ad hoc charging (without a subscription) is possible at most fast chargers, whereas this was not always the case for regular charging.

Netherlands Enterprise Agency published a helping hand for the automotive sector, to help them calculate the Total Cost of Ownership (TCO) of various car types and make sure a discussion on costs will be unambiguous.

Due to the Covid19 pandemic, companies and knowledge institutes have less money available to invest in sustainable solutions. A special R&D subsidy scheme was developed to stimulate innovation in the automotive sector. 8 Consortia involving 109 organisations received a total of 150 million EUR: 3 involved aviation, 3 maritime applications and 2 zero emission vehicles (1 on battery electric technology, 1 on hydrogen technology).

The Ministry of Infrastructure and Water Management organized an Innovation Challenge for start-ups to speed up electric driving for passenger cars. A professional jury judged the 39 solutions (communication/behaviour/technical/ chargers/LEVs/ MaaS/sharing, amongst others…) that were entered into the competition. Runners-up were an innovative app by Tap Electric and carsharing SamenSlimRijdenZeist. The winner of 20,000 EUR was NLCharge, that uses 1 Energy Management System to control tens to hundreds of AC and DC chargers.

Figure 2: NL Charge wins Innovation Challenge. Photo courtesy: NL Charge.

HEVS, PHEVS, AND EVS ON THE ROAD

At the end of 2021, the number of electric vehicles on the road (over 380,000 cars), accounted for 4.3% of the total passenger car fleet. Almost two thirds of these are BEVs. The number of BEV passenger cars increased by 42% to 243,664, while the number of PHEVs increased by 37% to 137,663. It was the first time in years that the PHEV fleet showed substantial growth as well. At the end of 2021, 488 FCEVs drove around - an increase by 33% compared to 2020.

Over the year 2021, 29.8% of total new passenger car registrations were electric. Of these the majority was full electric: 19.8%; the share of PHEVs in new registrations was 9.9%. Other vehicle types also steadily increase in numbers, as can be seen from table 2. Already more than 25% of the total fleet of buses used for public transport is electric.

Figure 3: Electric passenger cars in Dutch fleet 2016-2021

Source: Dutch Road Authority, edited by RVO

Electric passenger cars in the Dutch fleet Dec 2016 - 2021

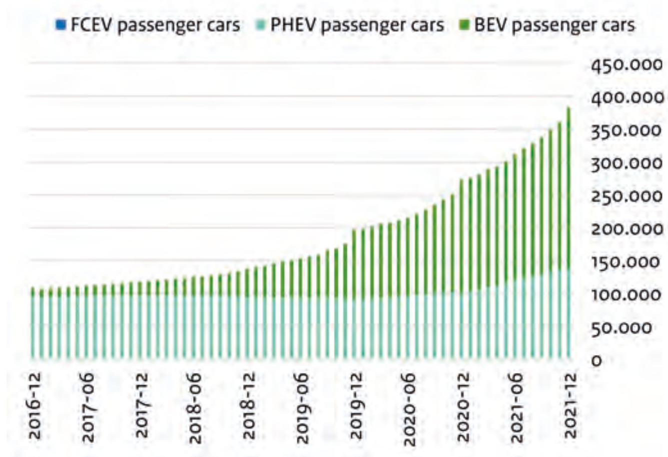

Table 2: Fleet totals end of 2021

Source: Dutch Road Authority, edited by RVO

*Total including ICEVs
** Speed pedelec only

Fleet Totals (as of December 31st 2021)

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike**	78,134	38	n.a.	n.a.	1,282,664
Electric moped (<50 kmph)	n.a.	n.a.	n.a.	n.a.	
Auto-rickshaw	1,063	4			743,347
Motorcycle	n.a.	n.a.	n.a.	n.a.	
Motorcycle with sidecar	126	9	n.a.	n.a.	14,717
Motorized tricycle	1,351	114	5	41	9,155
Passenger vehicles	243,664	342,270	137,663	488	8,826,160
Buses and Minibuses	9,035	777	77	15	1,045,008
Light Commercial vehicles	206	29	29	14	160,050
Medium and Heavy Weight Trucks	63	5	n.a.	8	11,879

Table 3: Total sales year 2021

Source: Dutch Road Authority, edited by RVO

*Total including ICEVs

Total Sales 1st Jan 2021 to 31st Dec 2021

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	4,009	n.a.	n.a.	n.a.	4,009
Electric moped (<50 kmph)	26,631	n.a.	n.a.	n.a.	74,185
Auto-rickshaw	n.a.	n.a.	n.a.	n.a.	n.a.
Motorcycle	288	n.a.	n.a.	n.a.	15,578
Motorcycle with sidecar	n.a.	n.a.	n.a.	n.a.	n.a.
Motorized tricycle	8	n.a.	n.a.	n.a.	753
Passenger vehicles	60,993	68,523	30,668	110	308,071
Buses and Minibuses	168	n.a.	n.a.	17	329
Light Commercial vehicles	3,081	490	53	n.a.	62,742
Medium and Heavy Weight Trucks	63	5	n.a.	8	11,879

The Netherlands has 970,000 users of shared car mobility and 87,825 shared cars (all fuels and all types of sharing). Of these, 11,500 or 13.1% were electric (BEV/PHEV) – a much larger share than in the general fleet.

CHARGING INFRASTRUCTURE OR EVSE

The Netherlands has a well-developed network of charging points, as is illustrated in figure 4, that shows the division of (semi)public charging points over the provinces. All charging is interoperable in the Netherlands, as has been the case since 2011.

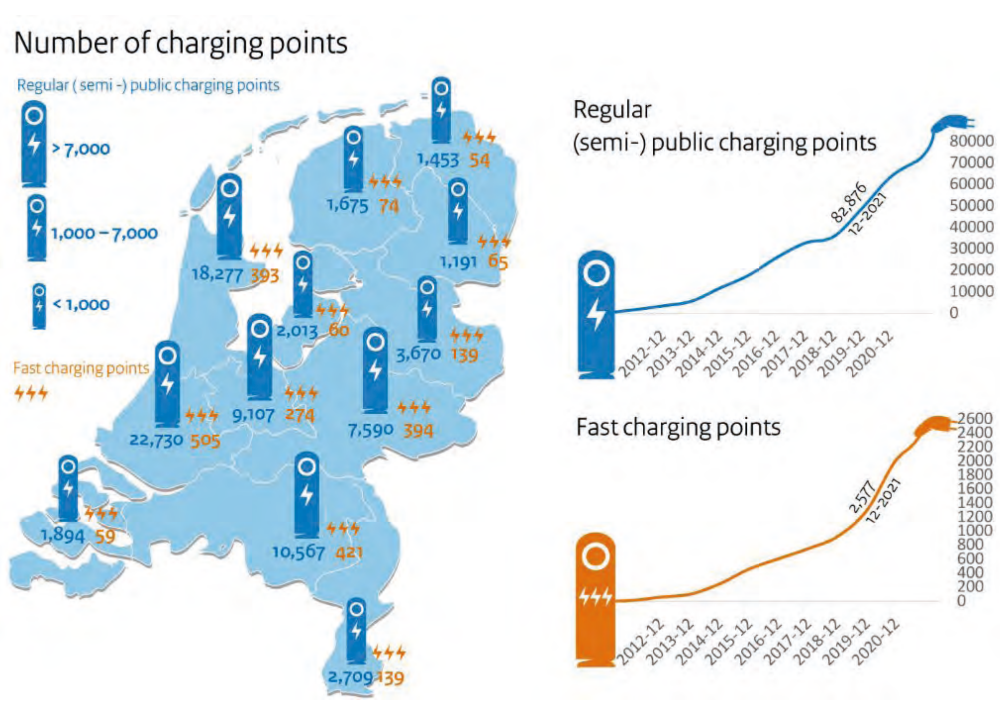

Figure 4: Number of charging points

Source: Eco-Movement, edited by RVO

Compared to the end of 2020, the number of (semi) public charging points increased by 30% in 2021. Fast charging can be done at 629 locations with 2,577 charging points. At the end of 2021, an estimated number of 221,000 private charging points existed in the Netherlands.

The Dutch government, knowledge institutes and companies together call for the use of open standards and protocols in charging infrastructure, so as to stimulate innovation and global access – thus favoring EV uptake.

Table 4: EVSE end of 2021

Source: Eco-Movement, edited by RVO

Type of Public EVSE	Number of Charging Points*[1]	Number of Locations*
AC Level 1 Chargers (≤3.7 kW)	2,031	38,353
AC Level 2 Chargers (>3.7 kW, ≤22 kW)	80,845	
AC Fast Chargers (43 kW)	293	629
DC Fast Chargers (≤50 kW)	977	
Tesla Superchargers (DC >120kW - 250kW)	821	
Ultrafast-High power chargers (DC >50 kW and ≤350 kW)	486	
Inductive Chargers (EM charging)	n.a.	n.a.

* As of December 31st 2021
1 Counted as EVSEs

At the end of 2021, there were 7 publicly accessible hydrogen fueling stations in the Netherlands, most of them supplying 350 and 700 bar.

EV DEMONSTRATION PROJECTS

In the provinces of Gelderland and Overijssel, CPO Allego, DSOs Enexis and Alliander and knowledge center ElaadNL conducted a large-scale smart charging pilot. Almost 1,000 charging poles were involved for three years. Public charging points worked with lower charging speed between peak hours 17:00 to 21:00, whereas outside of these hours more power could be supplied. Drivers also had the possibility to overrule the charging profile, but this was hardly used. The pilot showed that there is great potential in using smart charging for peak shifting.

In 2020 and 2021, 46 smart charging plazas were developed in 19 Dutch municipalities in the Living Lab Smart Charging Plazas. Within the living lab, smart and innovative techniques are tested to learn how to apply smart charging in the best possible way. The participating municipalities will share the knowledge they have acquired, so that all municipalities in the Netherlands can benefit. The Ministry of Infrastructure and Water Management subsidized the charging plazas with 5 million EUR.

Figure 5: Smart charging plaza Rotterdam using Artificial Intelligence. Photo courtesy ElaadNL

The demonstration scheme on Climate Technologies and Innovations in Transport (DKTI-transport) focuses specifically on entrepreneurs and partners in the transport, mobility and construction chain who want to invest in low carbon solutions. To accelerate the transition, the development of low carbon vehicles and vessels, and the deployment of corresponding charging and refueling infrastructure is supported. Two examples of projects:

- FUNDA(ce)MENT has the goal to show in a realistic user environment that emission-free construction transport and an emission-free construction site are possible.
- Empowering Zero Emission Supply Chain has the goal to experiment with zero emission bulk transport (orange juice) in the Rotterdam fruit harbour, in combination with an all-electric production facility.

In the MOOI subsidy scheme (mission-oriented research, development, and innovation), several projects run around smart solutions for a reliable, affordable, and equitable supply of electricity. One of them is FLEXINet of the Technical University of Delft. It centers around improving the sustainability of the electricity system and creating intelligent flexibility. This is done through integrated hybrid storage technologies by combining stationary battery storage, recycled batteries, charging electric vehicles, V2G technology, and flexible heat pumps.

OUTLOOK

The European Green Deal with the Fit for 55-package will continue to be further scoped and implemented in the years to come, serving as guidance.

In 2022, two new emission-free purchase subsidy schemes will be introduced, one for heavy duty vehicles and one for construction material such as excavators or concrete mixers. Converting diesel machines to battery electric or hydrogen machines will also be applicable.

Starting 24th January 2022, a subsidy will also be available for owner's associations of apartment buildings to get advice on charging points. How to do this in a parking garage? How to distribute costs fairly? How is this done safely? What about cyber security issues? The advice can cover these kinds of questions and facilitate a balanced and positive decision on chargers.

There will be more and more attention to charging for commercial logistical vehicles, as this is the next big transition to tackle. And further work will be done to approach e-mobility in an integral way, by taking into account the other subsectors of the energy transition, so as to better match the future electricity needs and supply.

Norway

MAJOR DEVELOPMENTS IN 2021

Policies

The overall target for Norwegian vehicle policy is to support Norway's climate policy targets of reducing greenhouse gas emissions by 50-55% in 2030 compared with 1990 [Regjeringen 2021]. The vehicle sector targets [NTP 2017], are to only sell zero-emission passenger vehicles, small light commercial vehicles, and city buses from 2025, and for 75% of coaches, 100% of large light commercial vehicles, and 50% of trucks sold to be zero-emission by 2030.

Norway has very large incentives for electric passenger vehicles (EU M1/M1G category). BEVs and FCEVs are exempted from the registration tax and the Value Added Tax (VAT), which are levied on fossil fuel powered vehicles upon purchase. These exemptions make BEVs a cheaper option than ICEVs in most vehicle segments. In addition, BEVs have reduced annual tax, and several driver privileges with substantial economic value. The annual tax is levied as a tax on insurance with a fixed cost per day. ZEVs were exempted up to 2020, but from 2021 it was introduced a 30% reduction compared to what ICEV owners pay. Table 1 provides an overview of the current status of the legislation.

The main change to policies is a continued gradual scale down of incentives. Last year, the reduced company car tax was revised. It was decided in December 2021 that for 2022, the advantage for ZEVs versus ICEVs is reduced from 40% to 20%, i.e., the list price used for calculation of the advantage is 20% reduced compared to ICEVs instead of 40%.

The change of vehicle ownership tax is also revised. BEVs were 100% exempted from 2018-2021, but the rate from 2022 will be 25% of the rates applied to ICEVs.

The tax will increase on most PHEVs from 2022. PHEVs get a rebate from the weight before calculating the weight tax. From 2022, the maximum rebate will be 15% if the all-electric mode range is 100 km. If the range is shorter, the weight rebate will be smaller.

* Equals EU court but for EEA topics

The European Economic Area (EEA) Surveillance Authority (ESA*) has approved current Norwegian policies through 2022. A new approval request will have to be sent to ESA during 2022 to get approval for a continuation of incentives or for revised incentives for the period after 2022. The parties of the current government have stated an intention to introduce VAT on the most expensive ZEVs, or rather the part of the price that is above a certain price point (60000 Euros). The local incentives are being scaled back to a 50% advantage compared to ICEVs for parking fees, road tolls and ferry fees.

Fleets

The national fleet of passenger BEVs (M1, M1G categories) reached 15.8% of the total national fleet, and passed 30% in Bergen, with Oslo close behind at 28%[3]. These high shares are positively impacting ambient air quality[3]. The bus fleet in Oslo is on its way to become fully electric by 2023[4] and the share is 40% from 2022. The share of electric buses in Bergen reached 25% in 2021[5]. An interesting development was the introduction of 10 battery electric buses in the mountain regions of Viken County, trafficking between Hemsedal and Gol[6], a distance of 32 km.

Markets

The ZEV markets are target and incentive driven in the passenger vehicle and LCV segments, and tender driven in the bus segment. Battery electric propulsion is becoming the standard for passenger vehicles and city buses, as seen by the high market share of BEVs in the passenger vehicle segment, and the fact that most of the latest tenders for buses have been won by those that offer full or partial battery electric bus fleets. The market for battery electric LCVs has been slow, as the incentives are smaller than for passenger vehicles, but the market share did increase in 2022. The battery electric truck market is still in its infancy.

Infrastructure

Norwegian charging infrastructure has over the last years scaled up in line with the increasing size of the BEV fleet. Most fast chargers that were installed in 2021 had a power level above 50 kW. Level 1 public chargers are rapidly replaced by Level 2 charging equipment. The first inductive chargers were installed for a taxi demonstration project, and NIO has built the first battery swap station in Europe at Lier 30 km from Oslo. It was tested at the end of 2021, but officially opened in January 2022. Tesla has continued to build out its Supercharger network.

Table 1: BEV incentives in Norway.

* 10 NOK = 1 Euro

Incentives	Intro year	BEV buyers - relative advantage*	Future plans
Fiscal incentives: Reduction of purchase price/yearly cost gives competitive prices			
Exemption from registration tax	1990/ 1996	The tax is based on ICEV emissions and weight and is progressively increasing. Example ICEV taxes: VW Up 3,000 €. VW Golf: 6,000 €	To be continued until end of 2022. ESA needs to approve a continuation or a revision.
VAT exemption	2001	Vehicles competing with BEVs are levied a VAT of 25% on sales price	To be continued until end of 2022. ESA needs to approve a continuation or a revision.
Reduced annual tax (a tax on vehicle insurance)	1996/ 2004	ZEVs exempted until end of 2020. From 2021: BEVs and FCEV 213 €, diesel/petrol: 297-307 € (2021-figures).	To be continued indefinitely.

Incentives	Intro year	BEV buyers - relative advantage*	Future plans
Reduced company car tax	2000	The company-car tax is 20% reduced compared to ICEVs, but BEVs are seldom bought as company cars.	The advantage was reduced from 40% in 2021 to 20% in 2022. Decided in annual national budgets
Reduction of change of ownership tax	2018	Change of ownership tax: ICEVs 0-3 year-old +1200 kg: 668 Euros, 4-11 years 403 Euros. BEVs: 25% of ICEV rate	Up to 2021, it was a 100% reduction. From 2022, the reduction is 75%.
Direct subsidies to users: Reduction of variable costs and help solving range challenges			
Reduced toll roads	1997	In Oslo users save 60%, 360-600 €/year. Some places savings exceed 1500 €	Law revised so that rates for battery electric vehicles on toll roads and ferries will be decided by local governments, up to a maximum rate of 50% of the ICEV rate.
Reduced fares on ferries	2009	Similar to toll roads, saving money for those using car ferries.	
Financial support normal chargers	2009	Reduce investors risk, reduce users range anxiety, expand usage.	National plan for charging infrastructure has been developed, but is rather vague.
Financial support for fast chargers	2011-	More fast-charging stations influence BEV km driven & market shares.	ENOVA** have supported fast chargers along major corridors and in municipalities without chargers. City fast charging left to commercial actors.
Electricity tax: 1.62 €C/kWh. Much less than fuel taxes		Gasoline road use tax: 49,1 €C/litre Gasoline CO2-tax:12,6 €C/litre Diesel: 36,2 + 14,5 €C/litre respectively	Road use tax to be continued until it can be replaced by GPS road pricing
User privileges: Reduction of time costs and providing users with relative advantages			
Access to bus lanes	2003/ 2005	BEV users save time driving to work in the bus lane during rush hours.	Local authorities have the authority to introduce restrictions if BEVs delay buses.
Free or reduced parking fees	1999	Users get a parking space where these are expensive and save time.	Local authorities can since 2017 charge BEVs up to 50% of ICEV rates.
Free charging (some places)		Not regulated by national law, but often bundled with free municipal parking	Local authorities and parking operators decide whether this incentive continue.

** ENOVA, a Government agency, supports the introduction of energy saving and climate gas reduction technologies in Norway. It supports charging infrastructure and infrastructure for alternative fuels.

HEVS, PHEVS, AND EVS ON THE ROAD

The BEV fleet in 2021 constituted 15.8% of the total passenger vehicle fleet, with PHEVs constituting another 6.4%. A total of 647691 vehicles, 22.2% of the total fleet, thus had a plug at the end of 2021. Only 190 FCEVs were in the fleet. 2.3% of the mopeds, 0.7% of the motorcycles, 3.6% of buses, 3% of LCVS and 0.1% of trucks were also battery electric driven. Plug-in hybrids are mainly found in the passenger vehicle segment, but 0.5% of buses and 0.1% of LCVs also use this technology. Four fuel cell trucks are currently being tested out in a development and demonstration project at a grocery wholesaler.

Table 1: Vehicle fleet[7]

*Total including ICEVs

Fleet Totals (as of December 31st 2021)

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	n.a.	n.a.	n.a.	n.a.	n.a.
Electric moped (<50 kmph)	3 505	n.a.	n.a.	n.a.	154 340
Auto-rickshaw	n.a.	n.a.	n.a.	n.a.	n.a.
Motorcycle	2 189	n.a.	n.a.	n.a.	312 504
Motorcycle with sidecar	n.a.	n.a.	n.a.	n.a.	n.a.
Motorized tricycle	n.a.	n.a.	n.a.	n.a.	n.a.
Passenger vehicles	461 661	115 924	186 030	190	2 916 708
Buses and Minibuses	538	106	69	0	14 908
Light Commercial vehicles	15 133	340	319	1	507 144
Medium and Heavy Weight Trucks	96	9	2	4	68 288

The passenger vehicle market set an all-time high record in 2021, of 176276 new vehicles sold and 18283 secondhand vehicles imported and registered, for a total of 194559 vehicles[8,9]. BEVs had a record high market share of 64.5%, with 113715 sold new and 10472 imported second hand, of which most were almost new, whereas the PHEV market share was 21.7%[8,9,10]. The share of vehicle sold with a plug was thus 86.2%. Only 41 FCEVs were sold in 2021.

The passenger vehicle market is currently on track to reach the national policy target[2] of only selling ZEVs from 2025, although it may be more challenging to replace the final percentage of ICEV sales. Of the new BEVs sold, 34449 were registered on companies, of which it is estimated that 13765 were leased to consumers[10]. In total, consumers thus bought or leased 93031 BEVs in 2021, which was 81.8% of the total number of new BEVs sold. The second biggest market in terms of market share is battery electric mopeds, which had a share of 35%.

The battery electric light commercial (BE-LCV) market reached new heights with 5520 vehicles sold, a 15.9% market share, which is far from being on course to meet the national target of only selling zero-emission small LCVs from 2025 and only zero-emission large LCVs from 2030. The biggest difference between 2020 and 2021 was for large LCVs, whose market share of 18% actually passed that of small LCVs that had a market share of 14%. In 2021, the market share of large battery-electric LCVs was much smaller. The reason for this development was the launch of a new series of medium and large LCVs from the Stellantis group (Peugeot, Citroën, Opel, Fiat, also as a Toyota version).

The public transport bus market is controlled through tenders for which the environment is an important competitive factor. In some cases, it is a basic requirement to use battery electric buses in the tenders, whilst in other cases it is a competitive factor together with other items. The result has been that battery electric buses have been phased in rapidly in many cities, but the registration numbers reflect the market the year the tender was won, typically a delay of 1-2 years. The market share of battery electric buses in 2021 was 9.3%. In the city bus segment, it was 13.5% and in the coach segment 3.7%. Plug-in hybrid coaches had a 1% market share in the coach segment. For the first time, 10 battery electric buses will be used in rural public transport in one of the mountainous regions of Norway[6].

Battery electric trucks had a market share of 1.3% with a sale of 64 trucks. The market has changed from modified trucks to series produced trucks from the large manufacturers, such as Volvo, Scania, and Mercedes[11]. The total cost of ownership (TCO) is currently high[11]. These first trucks are therefore used for demonstration and specific tasks where they can be competitive due to terms in transport contracts. The TCO is expected to become competitive around 2025[11].

It can additionally be noted that the number of battery electric powered ferries increased from 31 at the start of 2021 to 48 at the end[12]. The first cargo ship with battery electric propulsion via a 6.8 MWh battery pack, the Yara Birkeland, was taken into use in November 2021[13]. The plan is to gradually introduce autonomous operation for this vessel.

Table 2: Vehicle sales[7]

*Total including ICEVs

**A rough estimate is 70000-80000 [14]

Fleet Totals (as of December 31st 2021)

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	n.a**	n.a.	n.a.	n.a.	n.a.
Electric moped (<50 kmph)	1 053	n.a.	n.a.	n.a.	3 021
Auto-rickshaw	n.a.	n.a.	n.a.	n.a.	n.a.
Motorcycle	n.a.	n.a.	n.a.	n.a.	n.a.
Motorcycle with sidecar	n.a.	n.a.	n.a.	n.a.	n.a.
Motorized tricycle	n.a.	n.a.	n.a.	n.a.	n.a.
Passenger vehicles	122 539	14 427	40 115	41	196 110
Buses and Minibuses	104	0	5	0	1 120
Light Commercial vehicles	5 520	227	286	n.a.	33 155
Medium and Heavy Weight Trucks	64	0	0	0	4 883

CHARGING INFRASTRUCTURE OR EVSE

Most of the fast chargers that were installed in 2021 had a power above 50 kW, but chargers at 150 kW and higher can often be split in two to provide half power to two BEVs simultaneously. Fast charging with AC at 43 kW is being phased out, but some older chargers are in operation. There are still a number of AC level 1 chargers in operation, of which 99% use the Schuko domestic type outdoor socket, and 1% a Type 1 socket.

The first inductive BEV chargers were deployed in Oslo's inner city for a taxi demonstration project[15,16], and the first battery swap station for Nio opened in January 2022 for pilot testing at Lier, about 30 km from Oslo[17].

Table 3: Charging infrastructure status 31st December 2021 [18]

*As of December 31st 2021
** Of which 99% use the Schuko outdoor domestic socket type.
*** Includes 3.68 kW type 2 chargers (230V, 16A)

Type of Public EVSE	Number of Charging Points*	Number of Locations*
AC Level 1 Chargers (≤3.7 kW)	3046**	n.a.
AC Level 2 Chargers (>3.7 kW, ≤22 kW)***	9833	n.a.
AC Fast Chargers (43 kW)	49	n.a.
DC Fast Chargers (≤50 kW)	1627	n.a.
Tesla Superchargers (DC >120kW - 250kW)	1085	n.a.
Ultrafast-High power chargers (DC >50 kW and ≤350 kW)	1323	n.a.
AC other (3.6 kW – 22 kW)	39	n.a.
Tesla (Destination) (11-22 kW AC)	44	n.a.
Inductive Chargers (EM charging)	2	1 (3 planned)
Battery swap station (For NIO BEVs)	1 under testing	1

EV DEMONSTRATION PROJECTS

The zero-emission market in Norway, especially regarding battery electric solutions, has now moved past demonstration. Most of the zero-emission activities in Norway are 100% commercial, i.e., the Government has set up national and local incentives that the market reacts to. There are therefore just a few examples of demonstration programs.

Inductive charging of taxis is currently being tested in Oslo city center (Figure 1). The idea is that the taxis can be charged automatically while waiting in line at the taxi stop for the next fare. One taxi stop has been equipped with two inductive chargers, that are buried in the road surface. Two more taxi stops will be equipped with the same chargers. Jaguar has supplied the I-Pace BEVs used in the demonstration program.

Figure 1: Inductive chargers (blue fields) at taxi stop in Oslo Center. Photo: Erik Figenbaum

Other vehicle segments are in a roll out mode, where the vehicles are taken directly into use by consumers and businesses and used for their daily transportation needs. Even battery electric trucks are put into daily services in the companies that buy them. They are thus not part of demonstration programs per se, but act as internal demonstrators for the companies owning them. For fuel cell trucks, there is an initiative to establish a demonstration project called H2-truck. This is an industry and research driven initiative in an early phase.

OUTLOOK

The BEV market will continue to remain strong in 2022, and the total BEV fleet will likely pass 500000 by May 2022, which will be a major milestone. During 2021, a number of 4WD mid-sized SUVs, such as the VW ID.4, came on the market, but limited production volumes led to a lag in the deliveries of such vehicles to customers. Major deliveries will commence mid-2022 and contribute significantly to the expected strong market.

The influx of Chinese BEVs will continue, with NIO being the latest addition. NIO opened their first battery swap station at Lier 19.01.2022. NIO plans to install 19 more battery swap stations in Norway in 2022. These locations also have a few fast chargers.

Norwegian charging infrastructure is increasingly becoming an intricate web of actors, apps and payment solutions that is sub-optimal from a user perspective[19]. More customer friendly solutions should be introduced. For the traditional fast charger market, the trend is towards larger "charge parks" with 150 kW chargers. In January 2022, Tesla opened 15 of the Supercharger locations for all BEV owners, with "fair" pricing[20]. The plan is to test out how this works before considering opening more Superchargers to all BEV owners.

From January 2022, 109 battery electric buses[21] will be introduced in the Oslo Southeast area, so that the total number of BE buses in the Oslo area will reach 265, which covers 40% of the Oslo city bus operations[22]. A bus tender that was awarded in 2021 contained 100% battery electric bus operation in Oslo city center with a fleet of 180 additional BE buses from 2023[4]. The five inner Oslofjord passenger ferries operating from the Oslo Harbor will be 100% battery electric from the summer of 2022[22]. A long tender process ended with the contract to develop and put into service hydrogen ferries for the ferries trafficking across the 3-4 hours stretch across the rough Vestfjorden between the mainland (Bodø city) and the Lofoten Islands[23].

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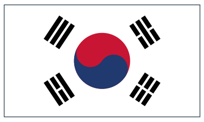

Republic of Korea

MAJOR DEVELOPMENTS IN 2021

Hydrogen fuel cell south Korea

South Korea (Korea) is betting big on hydrogen. Sustained public and private investment since the turn of the century has meant Korea is a key global market in the nascent hydrogen economy.

The country accounts for fully one-third of the world's installed capacity of utility-scale stationary fuel cells, and its largest automotive company, Hyundai Motors, launched the world's first commercial fuel cell vehicle in 2013, as well as the world's first fuel cell truck in 2020. Korea now plans to embark on a huge capital investment drive to build on these early successes, all of which should create strong opportunities for British firms in the space.

Korea's hydrogen industry is forecast to almost double in size, from KRW 14.1 trillion (£9.1bn) in 2020 to KRW 26.8 trillion (£17.3bn) by 2030. This growth will be driven by investments from large local players, such as Hyundai and Doosan, who increasingly see hydrogen as a key growth engine. Hyundai Motors intends to spend KRW 7.6 trillion (£4.9bn) under its 'Fuel Cell Vision 2030' programme and looks well placed to capitalise on its early-mover advantage in fuel cells, both by selling its own vehicles and by licensing its fuel cell systems to OEMs around the world.

With POSCO's recent retreat, Doosan now dominates Korea's large-scale stationary fuel cell market, and with its growing portfolio of fuel cell technologies, the company looks set to become competitive in other stationary power applications, such as the residential and commercial markets. This level of ambition is matched by a Korean government that sees hydrogen as part of the solution to the high carbon intensity of the country's economy.

In 2017, President Moon announced his 'New and Renewable Energy 3020' policy, which looks to increase the proportion of new and renewable energy in the overall generation mix to 20% by 2030. This difficult target - the current figure is 8.8% - reflects the action required to reduce emissions 37% against business-as-usual levels by 2030, a pledge Korea made at the United Nations Climate Change Conference (COP 21) in Paris in 2015. Building on this, the Korean government announced its Hydrogen Economy Roadmap in 2019.

Founding

By updating ambitious hydrogen plans and regulations, the Korean government is arguing for an active transition to a hydrogen economy. Three major factors have just been disclosed by the Korean government: a plan, a legislation, and a vow. A hydrogen plan was the initial driver.

In January of this year, the Korean government launched the "hydrogen economy activation strategy," with the goal of producing 6.2 million fuel cell electric vehicles by 2040. This strategy, which focuses on the energy sector, has a goal of delivering 15 GW of hydrogen fuel cell power generation by 2040. This is in keeping with South Korea's third basic energy plan, which emphasizes the relevance of hydrogen in the country's future energy mix. In addition, the government has released a national hydrogen economy strategy, which stresses the creation of a hydrogen model city in Ansan, Ulsan, and Wanju[1].

On July 14, 2021, one year after the launch of the first Korean New Deal, the government announced the update, the Korean New Deal 2.0. Through investment and legislative reform, the Korean New Deal has advanced remote work and education, encouraged low-carbon and environmentally friendly manufacturing, and spearheaded the country's transition to a green and digital economy. The international world has taken notice of the national strategy as acceptable strategies for dealing with the pandemic and climate change. The Korean New Deal 2.0 will increase fiscal investment planned to be made by 2025, from 160 trillion won to 220 trillion won[2].

Korea has made the first hydrogen-related act named Hydrogen Economy Development & Hydrogen Safety Management Act, that was passed on Jan 9, 2020[3].

The following are five tasks for the growth of the hydrogen industry[4]. To begin, more investment in the development of core sources and commercialization technologies is required to reinforce the basis of the hydrogen sector and ensure economic viability. Even though Korea's scientific proficiency in hydrogen automobiles and fuel cells is regarded as sophisticated, it still lacks internationally competitive levels of expertise in fundamental raw materials and components.

Furthermore, research and development is required to provide technical capabilities in the electrolysis and extractive hydrogen sectors, as well as liquid hydrogen and charging infrastructure, which are currently lacking in hydrogen production, storage, and transportation. To do this, efforts must be made through identifying and prioritizing goals for technology development to commercialization by developing a demand-driven R&D support system.

According to Article 10 of the Hydrogen Act, the South Korean government would give subsidies or loans for the development of hydrogen-related initiatives (including cooperative efforts with foreign entities). Article 13 allows private investment funds to be established for the purpose of investing in the hydrogen sector. The government will boost the maximum ceiling on loans to enterprises investing in hydrogen industries to USD$8.4 million and expand the USD$34 million Hydrogen Economy Fund[5].

A company must qualify as a hydrogen specialised company to get government assistance; such companies must either make at least 30% of sales from hydrogen-related businesses or devote 20% of their research and development expenditure to producing hydrogen-related goods. As of June 2021, the Hydrogen Act had designated 11 hydrogen-specialized companies.

Research

CORE TECHNOLOGIES OF THE E-GMP

Hyundai Motor Group has set 2021 as the start date for its road to global leadership in vehicle electrification. According to the Group, by 2025, it would have developed 23 eco-friendly car lines and sold over one million automobiles (or the market share of 10 %) A strong attempt will be made to electrify the South Korean, American, Chinese, and European markets by 2030; growing markets such as India and Brazil will have a goal date of 2035.

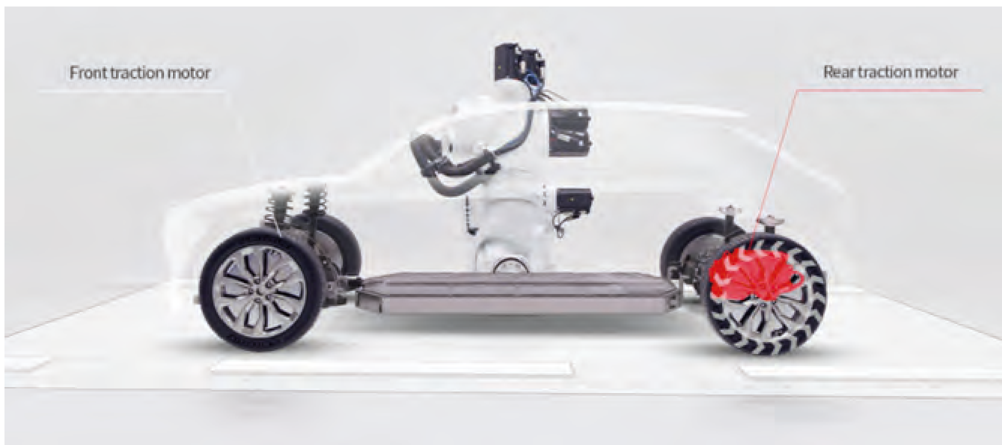

Figure 1: E-GMP’s design enables the 4WD feature.

E-GMP includes the PE System, which was designed to improve the driving performance of electric cars. The PE system, which is essentially equal to the powertrain of an ICEV, consists of the motor, EV transmission, inverter, and battery. The system is distinguished by four primary qualities. For starters, it's little. The technology avoids the waste of superfluous space by incorporating the motor, EV transmission, and inverter into one body, hence decreasing vehicle weight. The number of parts used to construct the battery was also decreased when compared to previous batteries, and this small battery module aids E-GMP in optimizing the EV's all-important range statistic.

Second, it is effective. The motor is now considerably more efficient, allowing the car to go further on the same battery capacity. The coils inside the motor were upgraded with 'Hairpin Winding' technology, which improved power generation efficiency, and the cooling method was changed to a faster and more efficient oil cooling system, in which the lubricant used in the EV transmission is cooled and sprayed directly onto the motor.

Third, it is useful. The E-GMP engineers investigated several ways to make automobile charging as simple as possible. As a result of that inquiry, the 800V Ultra-High-Speed Charging system has been introduced to the E-multi-charging GMP's system, which, together with the conventional 400V charging, comprises the E-multi-charging GMP's system. Most existing charging stations are 400V, however 800V charging is gaining traction, particularly in regions of Europe. The E-GMP from Hyundai Motor Group is the world's first multi-charging system, which can accept either 800V or 400V charging without the need for additional equipment or manual modification by utilizing the built-in motor and inverter. Its 800V Ultra-High-Speed

Charging takes 18 minutes to charge up to 80% capacity, and only 5 minutes to provide 100 kilometers.

Finally, driving is enjoyable. The 'High Response' Motor system in 4WD is a lot of fun. The E-GMP has a high-output motor in the rear wheel and another motor in the front wheel, allowing for 4WD. The motor was placed lower than typical, and the excellent weight distribution and low center-of-gravity design allows E-GMP cars to turn sharper turns and operate at higher speeds more steadily. Furthermore, the rear-wheel multi-link and the Integrated Drive Axle (IDA) round out the E-GMP by significantly improving R&H (Riding & Handling) performance[1].

MAXIMIZING EV DRIVING PERFORMANCE

E-GMP includes the PE System, which was designed to improve the driving performance of electric cars. The PE system, which is essentially equal to the powertrain of an ICEV, consists of the motor, EV transmission, inverter, and battery.

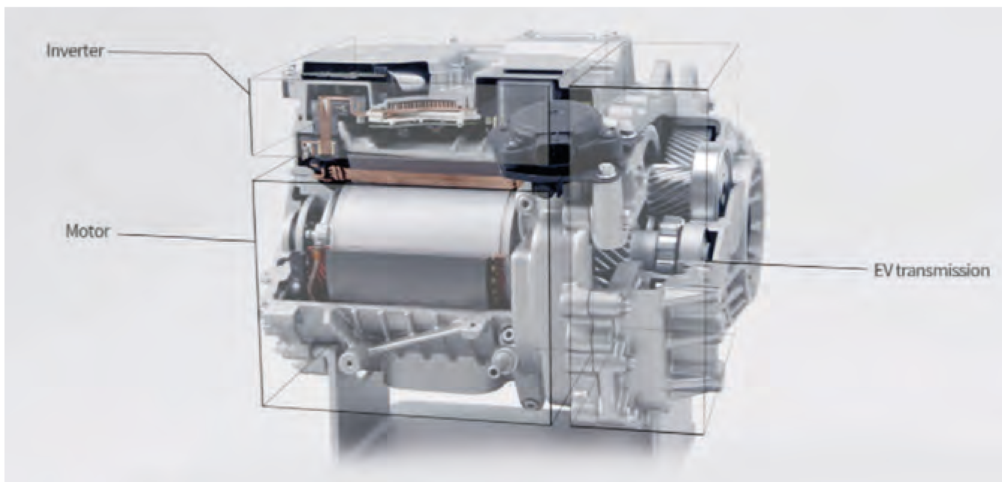

Figure 2: E-GMP incorporates the inverter, motor, and EV transmission into one body.

The system is distinguished by four primary qualities. For starters, it's little. The technology avoids the waste of superfluous space by incorporating the motor, EV transmission, and inverter into one body, hence decreasing vehicle weight (Figure 2). The number of parts used to construct the battery was also decreased when compared to previous batteries, and this small battery module aids E-GMP in optimizing the EV's all-important range statistic.

HEVS, PHEVS, AND EVS ON THE ROAD

As of July 2021, there were around 56.63 thousand units of electric vehicles sold in South Korea. According to EV-Volumes, the cumulative sales of battery and plug-in hybrid electric vehicles in South Korea were approximately 197.96 thousand units since 2012, which was the first year in which electric vehicle sales were recorded.

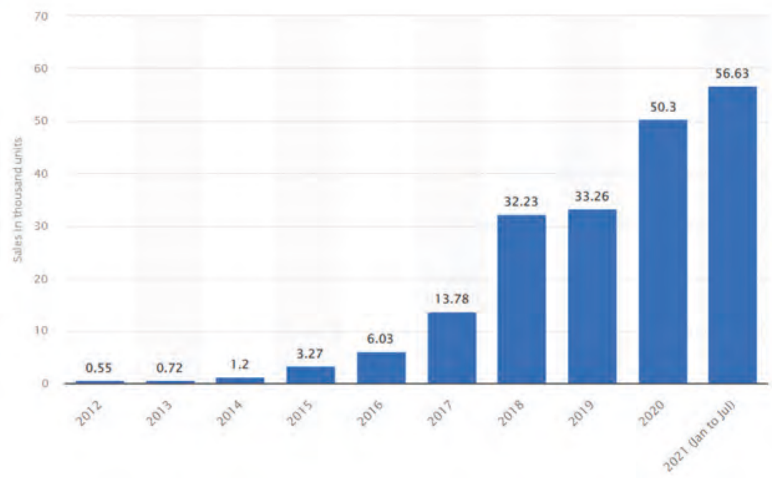

Figure 3: The cumulative sales of battery and plug-in hybrid electric vehicles in South Korea

Production: 263,723 Units, Domestic sales: 125,296 Units, Exports: 159,520 Units (Oct. 2021) The Ministry of Trade, Industry, and Energy announced on November 18 that automobile output, domestic sales, and exports decreased 21.6 %, 21.4 %, and 18.1 %, respectively, for the month of October. Despite the expectation that the global automotive chip shortage would ease in the third quarter, the supply from Southeast Asia was delayed, leading to cuts in production and exports. < Automobile industry statistics, October 2021>

The number of vehicles produced by Korean carmakers in October lost 21.6 % to 263,723 units. GM Korea and SsangYong Motor closed down temporarily due to the extended chip shortage. Domestic sales fell 21.1 % to 125,296 units due to delayed shipment caused by chip shortages. Both locally produced cars (down 21.5 %) and imported cars (down 23.5 % to 19,033 units) saw declines.

Meanwhile, green car sales in Korea jumped 61.4 % to 34,137 units. This accounted for 27.2 % of total domestic sales, setting a fresh high. All vehicle types showed growth. Hybrid electric vehicles (HEVs) increased 27.9 % to 20,413 units, plug-in hybrid electric vehicles (PHEVs) climbed up 93.3 % to 1,850 units, electric vehicles (EVs) soared 204.1 % to 10,934 units, and fuel-cell hybrid vehicles (FCEVs) expanded 46.9 % to 940 units.

Outbound shipments of automobiles in October went down 18.1 % to 159,520 units. The contraction is mainly attributable to the chip shortages. Shipments bound for the following regions increased: the EU (up 2.9 % to $661 million), Eastern Europe (up 20.9 % to $469 million), the Middle East (up 11.8 % to $432 million), Central and South America (up 38.8 % to $237 million), Oceania (up 15.2 % to $266 million), and Asia (up 29.5 % to $233 million).

Meanwhile, those bound for the following regions contracted: North America (down 24.8 % to $1.5 billion) and Africa (down 9.8 % to $37 million). However, green car exports improved 32.9 % to 38,538 units and the export value increased 41.8 % to $1.1 billion, both at record highs.

Shipments of all eco-friendly car types expanded. HEVs (up 29.1 % to 17,993 units), PHEVs (up 97.7 % to 3,774 units), EVs (up 27.4 % to 16,718 units), and FCEVs (up 55.9 % to 53 units) all contributed to the growth.

Auto part exports edged down 1.2 % to $1.8 billion, as the operation rates at overseas plants have yet to return to full capacity amid chip shortages. By export destination, auto part exports to the Middle East (up 9.2 % to $63 million), Asia (up 1.6 % to $495 million), Eastern Europe (up 24.3 % to $196 million), Africa (up 31.8 % to $6 million), and Oceania (up 34.6 % to $7 million) advanced, but those to North America (down 9.9 % to $512 million), the EU (down 3.7 % to $322 million), and Central and South America (down 3.7 % to $184 million) fell.

Table 1A: The units of electric vehicles sold in South Korea

Item	No of Vehicles Oct 2021	% change From Sep 2021	% change From Oct 2020	No. of Vehicles Jan - Oct 2021	% change From Jan - Oct 2020
Production	263,723	15.0	-21.6	2,840,219	-1.6
Domestic Sales	125,296	10.0	-21.4	1,428,226	-7.9
Domestically Produced Vehicles	106,263	16.5	-21.0	1,175,936	-10.9
Imported Vehicles	19,033	-16.1	-23.5	252,290	9.6
Exports	159,520	5.5	-18.1	1,680,863	10.3

Table 1B: Automobile and auto parts exports in value, October 2021

Item	Oct 2021 $100million	% change From Sep 2021	% change From Oct 2020	Jan - Oct 2021 $100million	% change From Jan - Oct 2020
Auto	38.3	7.6	-4.7	381.2	27.9
Auto Parts	17.9	-3.7	-1.2	188.2	28.8

CHARGING INFRASTRUCTURE OF EVSE

The most urgent works for the expansion of electric vehicles is the establishment of charging infrastructure. Charging infrastructure can be divided into rapid charging station, slow charging stand and mobile charger.

South Korea plans to install 3,000 new fast-charging stations for electric cars throughout 2021. The Ministry of Finance also plans to include 43 ultra-fast charging stations for the first time this year and will subsidise carmakers to secure sites for at least another 80 HPC stations.

In detail, the government will deploy 2,280 charging stations at locations like “express service facilities” where private entities have been reluctant to install charging stations due to high costs, the Korea Herald reports. We translate this as private supermarket sites or their parking garages, for example.

The new strategy of chipping in where private investors are reluctant also shows in further subsidies. The state will support private operators to install 289 sites at locations that are more accessible and profitable. The government will even subsidize 300 fast-charging stations at pit stops.

Add to this those first 43 high power charging stations and another 80 to be set up by the automotive industry with government support. The new high power charging funding has become necessary only as Hyundai and Kia launch their first electric cars with 800-volt systems this year.

Hyundai took a shiny HPC site online in Seoul just a few days ago (Figure 2). They offer eight High Power Chargers developed by Hyundai, each with charging capacities of up to 350 kW. The number of fast-charging stations in the country stood at 9,805 in 2020, according to the ministry. With the new 3,000 planned stations, the network should rise to over 12,000 DC charging sites.

For slower charges, South Korea had issued a blueprint last winter to have 500,000 EV charging stations by 2025, which is a steep rise from around 60,000+ units installed throughout the nation as of September 2020. New buildings must have a certain number of charging stations from 2022. The number of hydrogen fueling stations will reach 450 by 2025, jumping from 72 this year according to the new master plan.

Table 2: Electric vehicle charging infrastructures in Korea

Charging Type	~2018	2019	Nov 2020	Total
Total	27,352	17,440	17,997	62,789
Rapid	5,213	2,183	2,265	9,661
Slow	22,139	15,257	15,732	53,128

Figure 4: Vehicle charging connectors and vehicle sockets used in Korea

In February 2021, the government announced “the fourth basic plan for eco-friendly cars”, setting a target of planning to support the construction of chargers with more than 50% of the number of electric vehicles and supply ultra-rapid chargers that can supply energy to an electric vehicle to travel 300 km with a 20-minute charge.

Figure 4: Rapid charging stations

Type	Independent(Stand, Wall mounting) type	Socket type	Streetlight type
Shape			
Shape	7 kw	3 kw	3~7 kw
Charging time	7~8 hours	14~17 hours	7~17 hours

Figure 6: Slow charging stands and mounts

EV DEMONSTRATION PROJECTS

South Korea's major battery makers have pledged to invest 40.6 trillion won ($35.4 billion) in the electric vehicle battery industry over the next decade as part of a government-led initiative to position the country as the global leader. The investment will be led by three key players – LG Energy Solution Ltd., Samsung SDI Co. and SK Innovation Co. – will help them better compete against dominant players, such as China's Contemporary Amperex Technology Co. Ltd., commonly known as CATL.

Under the government-led initiative, the three battery majors will spend a combined 20.1 trillion won on research and development and invest 20.5 trillion won in facilities until 2030. In response, the government will support the companies developing next-generation battery technology, including solid-state batteries, and provide them with expanded incentives and tax breaks, according to a trade ministry statement.

The government, financial institutions and battery makers will jointly set up an 80 billion won fund to help small- and medium-sized firms strengthen their ability to provide battery-making materials and components. The ministry said it will foster some 1,100 battery-related experts annually, up from the current 50 professionals a year. As of last year, Korea led the global battery market with a 44.1% share, followed by China (33.2%) and Japan (17.4%).

To keep their Chinese rivals in check, the three Korean battery makers said they will raise their combined production capacity to 430 GWh a year by 2023, from 180 GWh in 2020. SK Innovation said in May it signed an initial agreement with Ford Motor Co. to launch a 6 trillion won JV, named BlueOvalSK, to manufacture batteries in the US. SK Innovation is already constructing two battery plants worth $2.6 billion in the US state of Georgia.

LG Energy Solution has formed an EV battery JV with General Motors Co. Their JV, Ultium Cells LLC, is building a $2.3 billion EV battery cell manufacturing facility in Lordstown, Ohio. In April, LG and GM announced that they will spend 2.7 trillion won to build their second US EV battery plant in Tennessee, which should double their EV battery output in the country. More recently, Samsung SDI said in June that it is considering launching a battery production joint venture in the US with a global automaker to gain ground in one of the world's biggest auto markets.

The wireless EV charging system is among the 10 pilot projects granted a regulatory sandbox, according to the Ministry of Science, ICT and Future Planning and the sandbox support center at the Korea Chamber of Commerce and Industry. Hyundai Motor's project envisions cordless charging of electric cars with receivers installed on the vehicles and at electric charging stations. Following the approval, Hyundai Motor is to become the first Korean carmaker to apply wireless charging technology to its EVs. The carmaker said it will start testing the service by the fourth quarter this year and collect data to prepare for related infrastructure.

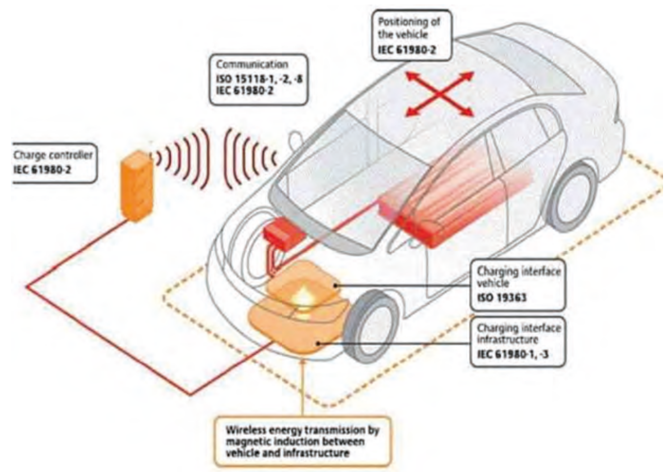

Figure 7: An illustrated demonstration of Hyundai Motor's wireless EV charging system.

Source: KCCI

Wireless charging stations for e-scooters will also make their debut. Users of scooter sharing services will no longer have to go to charging stations to plug in their vehicles but charge them remotely at designated areas. Other services that received a nod by the two institutions include a self-moving delivery robot, a hospital escort service, sharing kitchen service, and a startup named Covering, which recycles food waste and disposable containers leftover from food deliveries. "Following today's decision, KCCI's sandbox support center has approved more than 100 new services and technologies," said Woo Tae-hee, the business lobby's executive vice chairman. "The KCCI will actively work with the ICT Ministry and the Trade Ministry to support the revision of related laws."

KCCI's sandbox support center is the first private institution to support the government's regulatory sandbox initiative. Since the center's launch in May 2020, 104 products and services have received a special exemption under the government initiative.

OUTLOOK

Currently in Korea, 112 hydrogen filling stations are currently in operation across the country. *Aju Business Daily* writes that in 2022, 38 more filling stations are to be added. In December 2021, the number of twelve hydrogen filling stations currently in operation on motorways is to be increased to 43 in 2022 and to at least 52 in 2023. The project partners plan to jointly build another three hydrogen filling stations.

Industry in South Korea is ramping up its fuel cell capacities. Hyundai has been pushing the fuel cell vehicle drive in commercial vehicles and, for example, Plug Power and SK Group's SK E&S division formed their joint venture announced earlier this year to provide fuel cell systems, hydrogen fueling stations and electrolyzers to the Korean and other Asian markets in December 2021. Also in October just passed, Hyundai Mobis, the South Korean automotive supplier belonging to the Hyundai Motor Group, has announced that it will invest about 1.3 trillion won (equivalent to about 950 million euros) in the construction of two plants for fuel cell systems in the Korean cities of Incheon and Ulsan.

In South Korea, a total of 624 hydrogen buses are to be put on the roads of the port cities of Busan and Ulsan and the province of South Gyeongsang by 2025 as a replacement for buses with combustion engines. The country's Ministry of the Environment has signed a cooperation agreement to this effect with the cities and the province mentioned, as well as Hyundai. Aju Business Daily writes that about 300 million won (222,000 euros) in subsidies are being provided for each vehicle. An electric intercity bus with a fuel cell will also be tested, whereby the Ministry of Environment and Hyundai aim to collect data on the NVH (noise, vibration, harshness), economy and performance of the bus through the test operation. Such a FC intercity bus was first mentioned in a report last July when Hyundai announced it would be making the Universal coach in a hydrogen fuel cell version.

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Spain

MAJOR DEVELOPMENTS IN 2021

Relevant Strategies, Policies and Normative at National Level

The following are relevant new normative advances in 2021, related to electric mobility in Spain:

LAW 7/2021, OF MAY 20, ON CLIMATE CHANGE AND ENERGY TRANSITION
It introduces, for the promotion of electric mobility, the following obligations and mandates:

1. No later than 2040, only vehicles with emissions of 0 grCO2/km will be marketed.
2. The municipalities with more than 50,000 inhabitants will adopt, before 2023, sustainable urban mobility plans that introduce the establishment of low emission zones.
3. Obligations to install EVs recharging infrastructures at service stations, whose annual sales of gasoline and diesel exceed 5 million liters.
4. A mandate to the Government to develop, and make available to the public, an information platform on recharging points.
5. Forecast that the Technical Building Code will establish obligations related to the installation of recharging points in new buildings

ROYAL DECREE-LAW 27/2021, OF NOVEMBER 23
Modification of Article 43(bis) of Hydrocarbons Law, which regulates the contracts that wholesale operators may have with their franchisees or flag bearers. The possibility of exclusivity contracts that limit the deployment of electric vehicle recharging infrastructure is prohibited.

ROYAL DECREE-LAW 24/2021, OF NOVEMBER 2, ON THE TRANSPOSITION OF EU DIRECTIVES
Directive (EU) 2019/1161, on the promotion of clean and energy-efficient road transport vehicles, is transposed through this normative.

The purpose of this Directive is to ensure that contracting authorities and corresponding contracting entities take into account, in public procurement relating to road transport vehicles included in its scope of application, the energy and environmental impacts of these during their useful life, in order to promote and stimulate the market for clean and energy efficient vehicles and thus improve the contribution of the transport sector to environmental policies, environment, climate, and energy of the European Union.

Royal Decree-Law 24/2021 defines the public contracts to which it will be applicable and scope of application. It also defines what is meant by "road transport vehicle", "clean vehicle" and "zero emission heavy vehicle" for the purposes of the transposition rule.Additionally, it explains which vehicles are excluded from its application, and what are the "minimum public procurement objectives" of defined vehicles and services, expressed as minimum percentages of clean vehicles with respect to the total number of road transport vehicles included in the sum of all the contracts included in the scope of application.

ROYAL DECREE 1125/2021, OF DECEMBER 21
It regulates the granting of direct subsidies to electricity distribution companies to carry out investments in the digitalization of electricity distribution networks and in infrastructures for recharging electric vehicles, charged to European PRTR funds.

ROYAL DECREE LAW 29/2021, OF DECEMBER 21
It establishes the adoption of urgent measures in the energy field to promote electric mobility, self-consumption, and the deployment of renewable energies.

Among the most relevant measures to be implemented, the following stand out:

1. Installation of recharging points in road protection zones. The authorization system for these points is facilitated on the land adjoining these roads, under certain conditions, and provided that road safety is guaranteed.

2. Administrative simplification: Certain licenses are replaced by responsible declarations for the installation of charging points.

3. Obligations related to the installation of recharging points in existing buildings for use other than private residential and that have a parking area with more than twenty spaces, before 01/01/2023.

4. Tax reductions for certain local taxes related to infrastructure deployment.

Incentives Programs to promote EVs

MOVES III PROGRAM (INCENTIVE PROGRAM FOR ELECTRIC MOBILITY)

Royal Decree 266/2021 was published on April 14, 2021, by the Council of Ministers. The decree follows the line of previous editions of the Moves Program, and aims to promote the electrification of mobility, and the boost to industry and the associated business sector. MOVES III establishes direct granting to the different regions within the framework of the European Recovery and Resilience Facility, endowed with €400 million, which could be increased up to €800 million if there is an adequate commitment of funds and prior to the expiration of the term of validity.

This budget is aimed at encouraging the purchase of electric vehicles and the deployment of recharging infrastructure for these vehicles:

- Program of incentives for EV acquisitions: electric (and fuel cell) cars, vans, quadricycles, and motorcycles are supported within the framework of this program. The aided vehicles may be new or up to nine months old.

  The amount of the aid depends on the type of vehicle purchased, whether there is additional scrapping of another old vehicle, and on the type of beneficiary, with a range of aid amounts from €700 (electric motorcycles for large companies), up to €9,000 (vans with scrapping, for individuals).

  This aid can be increased by 10% for the purchase of passenger cars, in the case of individuals with reduced mobility and need an adapted vehicle, for taxis and VTC, and for inhabitants of municipalities with less than 5,000 inhabitants.

- Program of incentives for infrastructure deployment: for both private and public use of whatever recharging power. Also, it is supported pre-installation and communication services required, in the case of communities of owners (parking facilities of living blocks). Level of incentives is shown in the following picture:

Level of Incentives for infrastructure recharging, MOVES III Program

	Incentive (% eligible costs)	
	General placement	Municipalities <5.000 hab.
Individuals, , self employed, living blocks, public administration without economic activity	70%	80%
Companies and public entities with economic activity, with public service recharing and P ≥50kW	35% (45% Medium companies) (55% Little companies)	40% (50% Medium companies) (60% Little companies)
Companies and public entities with economic activity with private service recharging (any recharging power) or public service recharging with P <50kW	30%	40%

Depending on the type of beneficiary, the aid limit can reach up to €800,000 per request file, and up to €2.5 million for the same beneficiary throughout the validity period of the corresponding regional call (at the end of 2023).

Regarding the program monitoring, at the end of 2021 it was committed almost 40% of the budget assigned by Regional Administrations (CCAA) to incentives for vehicle acquisition, and almost the totality of the budget dedicated to infrastructure recharging (14 of the 19 CCAA have generated a provisional list of requests) by an amount of more than €50 million.

The budget will be increased at the request of the Autonomous Communities, during 2022.

MOVES SINGULAR PROJECTS II (INCENTIVES PROGRAM FOR ELECTRO-MOBILITY AND INNOVATIVE PROJECTS IN THE TRANSPORT SECTORS)

The Ministry for the Ecological Transition and Demographic Challenge approved Order TED/800/2021 on July 23, 2021, of regulatory bases of the Program of incentives for relevant projects in electric mobility (MOVES Program Singular Projects II), endowed with 100 million euros and aimed at the selection and granting, on a competitive basis, of aid corresponding to singular projects, and projects related to experimental and innovative developments, carried out in the national territory and related to the electric mobility, which could deal with the following matters:

- Electric mobility and ICT applications.
- Innovative electric vehicle recharging infrastructure, hydrogen recharging for vehicles, and integration with other smart grids.
- Applications of new battery developments and electrical storage for mobility.
- Projects for the development or innovation of new processes or prototypes of electric vehicle models or components.

MOVES Singular Projects II program is part of Component 1, Investment 2 of the Recovery, Transformation and Resilience Plan.

In the frame of this program, managed by the IDAE, projects with a minimum investment of 100,000 euros will be considered. Its call was made through the Resolution of September 20, 2021, of the General Director of IDAE.

The application submission period was from September 25 to November 25, 2021. A total of 173 applications have been received, far exceeding the budget available from €100 million.

The project is currently under evaluation.

MOVES FLEET PROGRAM (INCENTIVES PROGRAM FOR LIGHT VEHICLE FLEET ELECTRIFICATION PROJECTS)

On December 17, 2021, Order TED/1427/2021, of December 17, was approved, which regulates the bases of the Aid Program for light vehicle fleet electrification projects (MOVES FLOTAS Program), within the framework of the Recovery, Transformation and Resilience Plan (PRTR), and whose call for proposals was published on January 19, 2022.

The MOVES FLEET Program, managed by the IDAE, is part of the PRTR (Component 1, Investment 2) and complements the Programs published within the framework of the aforementioned component and investment, such as MOVES III and MOVES Singulares II. It is endowed with an initial amount of 50 million euros and is aimed at the selection and granting, on a competitive basis, of aid corresponding to projects for the electrification of light vehicle fleets, which operate in more than one region (of the 19 different autonomous regions and cities in Spain).

The projects may include, not only the acquisition of electric vehicles to replace combustion vehicles, but also the provision of the recharging infrastructure necessary for the new fleet at the company's facilities, as well as the acquisition or adaptation of management systems for fleets, to, among others, digitize the control of routes, as well as training company personnel in order to make a transition of the fleet towards electrification.

The projects require renewal of vehicle fleet, with a maximum of 500 and a minimum of 25 vehicles, per application. Beneficiaries can submit applications for a maximum aid amount of €2.5 million.

MITMA FLEET PROGRAM (INCENTIVES PROGRAM FOR HEAVY VEHICLE FLEET ELECTRIFICATION PROJECTS)

In order to promote the transformation of heavy professional vehicles, the Council of Ministers published on November 16, Royal Decree 983/2021, to establish direct granting to the different regions within the framework of the European Recovery and Resilience Facility, endowed with €400 million, for the transformation of passenger and freight transport fleets.

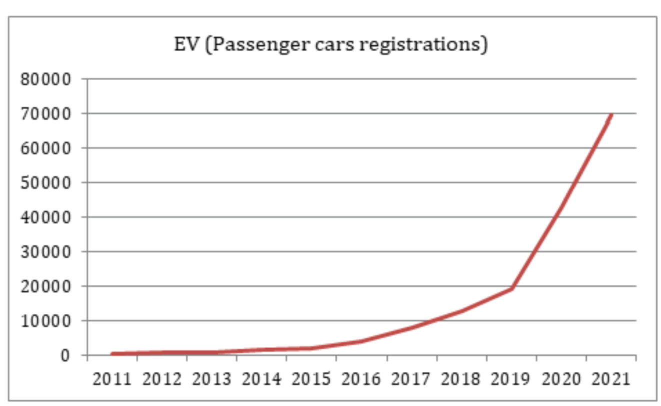
EVS AND HEVS ON THE ROAD

In the year 2021, **85,324 electric vehicles were registered in Spain**, consisting of BEVs, PHEVs and REEVs (Table 1), representing an increase of 42% respective of the previous year, with a total of 60,257 EVs registrations at the end of 2020. This increase was sustained by the continuity of incentives programs to support EVs acquisition at national scale (such as theMOVES II and MOVES III Plans), and also by other initiatives and incentive programs launched at other different levels of the public administrations.

In the specific case of electric passenger cars (BEVs, PHEV/EREVs), there were registered a number of 69,467 vehicles, **representing a market penetration of 7.3%** during 2021 (Figure 1). Considering both technologies, electric and conventional hybrid electric vehicles (HEVs), they accounted for a number of 293,298 vehicles, resulting in a market penetration of 30.8%.

Considering all vehicle categories (except electric bicycles), electric vehicles (BEVs, PHEVS and REEVs) fleet in Spain at the end of 2021, results in a total number of 221,592 (Table 2), representing an increase of 53.3% respective of the previous year 2019, which accounted for a total number of 144,585 EVs on the road.

Figure 1: EVs market evolution (annual sales of passenger cars) in Spain, 2011-2021



Focusing on conventional hybrid vehicles, it is remarkable the huge increase of the hybrid passenger car registrations along the five recent years (Figure 2), with a

specific number of 223,831 registrations during the year of 2021 (an increase of 60% respect 2020), starting from a number of 7,759 registrations during 2015.
It is remarkable in this way, the impact of the environmental car labelling, promoted by Spanish Traffic Authorities, and the different measures and initiatives implemented for air quality in regions and cities.

Figure 2: HEVs market evolution (annual sales of passenger cars) Spain, 2011-2021

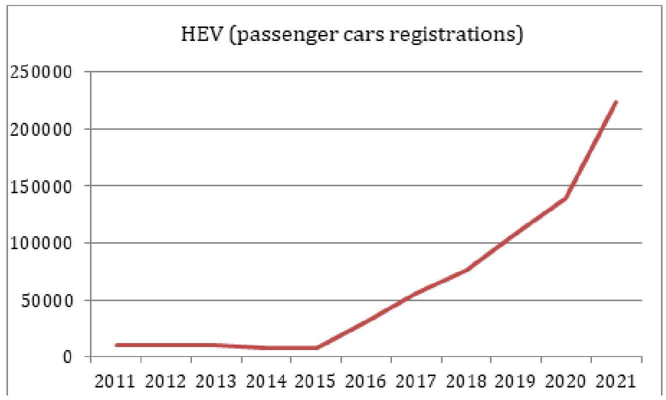


Table 1: Total sales of EVs and HEVs, per category (2021)

Source: IDAE, based on registrations of Spanish Traffic Authorities (DGT)

*Total including ICEVs
** Estimated data at the end of 2020 (Source: AMBE - Spanish Association of Bicycles and Brands)

Total Sales during 2021

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Bicycles (assisted pedaling)	250,000	0	0	0	1,570,000**
Mopeds (L1, L2)	5.789	0	0	0	18,887
Motorbikes (L3, L4, L5)	6.806	0	0	0	173,394
Quadricycles (L6, L7)	821	0	0	0	2,659
Passenger cars (M1)	25,204	223,831	44,263	9	953,594
Commercial vehicles (N1)	2.240	1,760	38	0	133,609
Buses (M2, M3)	130	412	16	2	2,092
Trucks (N2, N3)	16	6	1	0	35,334
Light Commercial vehicles	600	190	20	0	28,446
Medium and Heavy Weight Trucks	n.a.	n.a	n.a	n.a	n.a
Totals (without bicycles)	**41,006**	**226,009**	**44,318**	**9**	**1.319.569**

Table 2: Fleet totals of EVs and HEVs, per category (2021)

Source: IDAE, based on registrations of Spanish Traffic Authorities (DGT)

*Total including ICEVs
** Estimated data at the end of 2020 (Source: AMBE - Spanish Association of Bicycles and Brands)

Fleet Totals during 2021

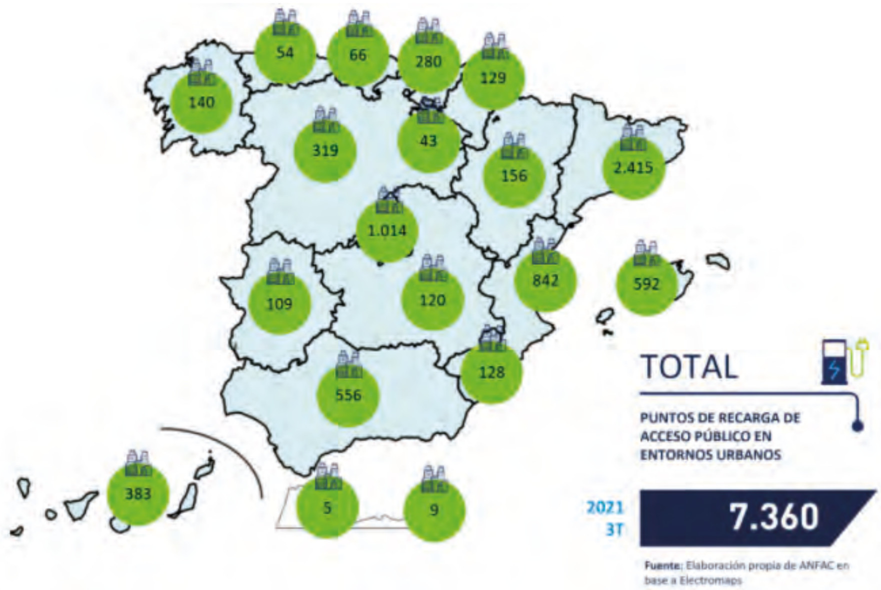
Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Bicycles (assisted pedaling)	910,000	0	0	0	30,000,000 approx.**
Mopeds (L1, L2)	25,391	0	0	0	1,809,102
Motorbikes (L3, L4, L5)	28,412	22	0	0	3,881,297
Quadricycles (L6, L7)	3,523	0	0	0	69,267
Passenger vehicles (M1)	66,362	684,873	86,833	18	24,970,836
Commercial vehicles (N1)	10,338	3,635	93	0	4,108,351
Buses (M2, M3)	426	1,633	87	2	63,644
Trucks (N2, N3)	103	297	24	0	955,853
Light Commercial vehicles	600	190	20	0	28,446
Medium and Heavy Weight Trucks	n.a.	n.a	n.a	n.a	n.a
Totals (without bicycles)	**134,555**	**690,438**	**87,037**	**20**	**35,858,350**

CHARGING INFRASTRUCTURE OR EVSE

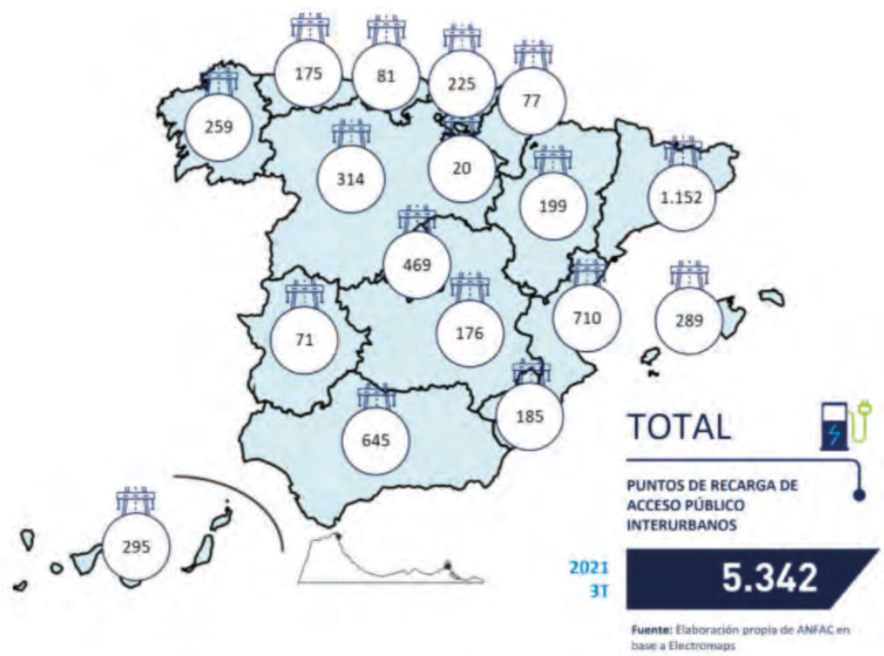
During 2021, official information about the number of charging points in Spain was not available. However, the National Government, through the State Secretariat for Energy, works on a European project for identification and placement of recharging points that will be available in 2022. According to estimations of the sector (Spanish Association of Car and Trucks Manufacturers –ANFAC- based on “Electromaps” data), at the end of September 2021 there are 12,702 charging points for public use (5,342 of them, placed on roads and the other 7,360 in urban areas), covering all the possible power ranges.

Considering that charging at home and in fleet places could cover around 85% of the needs, the other 15-20% should be covered by public charging points, known as “opportunity charging”.

Source: ANFAC, Recharging infrastructure in urban areas (September, 2021)



Source: ANFAC, Recharging infrastructure in principal corridors (September, 2021)



Related to power infrastructure, public use charging points in Spain, at the end of September 2021, can be classified in the following way:

Source: ANFAC, Recharging points in urban areas, classified per power, at the end of September, 2021

Power (kW)	P ≤ 22	22< P ≤50	50≤ P ≤150	150≤ P <250	P≥250
Charging points	6,550	265	497	2	46

Source: ANFAC, Recharging points on road, classified per power, at the end of September, 2021

Power (kW)	P ≤ 22	22< P ≤50	50≤ P ≤150	150≤ P <250	P≥250
Charging points	4.450	245	600	5	36

Finally, as mentioned before, related to public recharging points in non residential buildings with more than 20 parking spaces, it must be pointed out that the Royal Decree Law 29/2021 will facilitate the installation of a minimum of public use recharging points by January 2023.

The objective of PRTR in Spain is around 80.000- 100.000 recharging points by the end of 2023.

EV DEMONSTRATION PROJECTS

Some demonstration projects, carried out in Spain, are as follows:

Cirve Project ("Iberian Rapid Recharge Infrastructure Corridors> 40kw of Electric Vehicles")

The project “Iberian Corridors of Rapid Recharging Infrastructure for Electric Vehicles” (CIRVE) has been in development since December 2016. It was a project co-financed by the European Commission, through the 2015 call of the CEF Mechanism. The consortium is made up of eight partners (Endesa, Iberdrola, EDP, Ibil, Gic, Renault, Aedive and the Portuguese technology center CEIIA) and is supported by the governments of Spain (through the Ministry of Industry and the Ministry of Public Works).). In Portugal, there was a parallel project with other partners, although both share objectives.

The estimated cost of the project is €3,523,232 and UE maximum contribution €1,761,616 (up to 50%), for the deployment, at the end of 2020, of 40 fast charging points in Spain -and 18 in Portugal- (> 40 kW) for electric vehicles in strategic areas of the Atlantic and Mediterranean corridors that pass through Spain and Portugal.

AMBRA Project

AMBRA is a project co-financed by the European Commission, through the 2017-Blending call of the CEF Mechanism (Connecting Europe Facility), which aims to install high-power charging points (> 40 kW) for electric vehicles in Italy, Spain and Romania.

The Action aims to deploy and operate a network of Normal, Fast and Ultra-Fast Charging Stations (up to 350 kW) for electric vehicles in Europe, providing linked coverage for long-distance travels and enabling cross-border trips towards Italy, Spain and Romania in order to support these Member States to speed up in terms of electric vehicle infrastructure.

The Action intends to deploy 3,169 electric vehicle charging stations on 6 TEN-T Core Networks Corridors. The use of the charging points is expected to be possible either with ad-hoc payments or using any Mobility Service Provider in case of contract based charging.

Sweden

MAJOR DEVELOPMENTS IN 2021

The rate of electrification in the road transport sector has remained high in 2021, with a total increase over the year of 64%. 2020 ended with approximately 190,000 rechargeable vehicles and now, a year later, the milestone of 300,000 rechargeable vehicles has been passed.

A total of 309,114 rechargeable vehicles rolled out in Sweden, of which 109,735 are electric cars (BEV), 187,905 charging hybrids (PHEV), 2,361 electric motorcycles, 667 electric buses and 8,443 light trucks. Statistics from December show that 60% of new registrations were rechargeable vehicles. The trend has been for the electric car to approach numbers of the increasingly popular charging hybrid in new sales. During the fourth quarter of the year, pure electric cars accounted for 51% of all newly registered rechargeable vehicles. The corresponding figure for the same period in 2020 was 30%.

2021 was also the year when electrification of heavy vehicles gained momentum. Truck manufacturers are developing electric versions of heavy vehicles, and the number of rechargeable heavy trucks has more than doubled when they increased from 29 to 73. In December, the Swedish Electrification Commission launched an action plan with commitments and initiatives to accelerate the electrification of transport, several of which deal with how the electricity grids can meet the power demand from charging.

During the year, investments in the expansion of public charging infrastructure for the heavy vehicle fleet were presented through a joint venture between truck manufacturers Volvo, Daimler and Traton, with the aim of establishing at least 1,700 charging points in Europe for trucks no later than 2027.[1]

The first battery cell developed by the Swedish company Northvolt has now been manufactured in the factory in Skellefteå. The production will be scaled up 60 GWh. Together with Volvo Cars, Northvolt has decided to build another battery factory in Sweden, which will have an annual production capacity of up to 50 GWh.

Funding and Research

INDUSTRIKLIVET

Industriklivet, the Industrial step program can provide support for, e.g., strategically important initiatives, such as the application of new technology, or other innovative solutions within industry that significantly contribute to reducing greenhouse gas emissions in society, for example, in the areas of batteries and hydrogen. The program is handled by the Swedish Energy Agency.

FFI partnership program, the strategic vehicle research and innovation program
In 2020, the government reinforced Sweden's major transport research and innovation program (FFI), with 10 million EUR between 2021 and 2022, to support the research and development of heavy equipment in order to reduce greenhouse gas emissions.

THE SWEDISH ELECTROMOBILITY CENTRE (SEC)
The Swedish Electromobility Centre (SEC) brings the academia and automotive industry together, with a range of different research disciplines. All are connected through their relevance for electric and hybrid vehicle technology. They promote deep and narrow technological studies, cross-discipline, and cross-institution research. The work is focused within the five theme areas:

- System studies and methods
- Electrical machines drive systems and charging
- Energy storage
- Electromobility in society
- Interaction between vehicles and grid.

The Swedish Energy Agency, together with industry, public sector and academy, funds SEC that will accelerate the transition to a fossil-free society and will strengthen Swedish competitiveness. The total budget is 28 million EUR for the period 2022-2026.

SWEDISH ELECTRIC TRANSPORT LABORATORY (SEEL)
The Swedish Electric Transport Laboratory (SEEL) is a test center for research and development in the field of electromobility. It is owned and run by Chalmers[2] and RISE[3] as a joint venture. SEEL will establish three facilities - in Gothenburg, Nykvarn and Borås. The aim is to consolidate efficient knowledge development and improve the conditions for collaboration in the field of electrified transport in Sweden and Europe. Players in the automotive, aerospace, and maritime sectors, as well as other companies developing technology in relevant areas, will gain a common platform on which to meet, and will jointly benefit from the knowledge development and technology shift currently taking place.

At the same time, researchers at colleges of higher education, universities, and research institutes will gain access to advanced research infrastructure in the field of electromobility. The test bed will be operational by 2023. The test center is part of a European investment in a value chain for batteries. The SEK 575m state aid from the Swedish Energy Agency for the electromobility lab SEEL is being provided within the parameters of an Important Project of Common European Interest (IPCEI) in order to support the creation of a European battery value chain. The ten-year project involves 17 participants from seven member states. It includes major European investments in the field of raw and advanced materials for batteries, battery cells & modules and entire battery systems, as well as in the use, recycling, and refinement of recycled materials. The investment is being made within the parameters of the European Battery Alliance[4].

HEVS, PHEVS, AND EVS ON THE ROAD

In 2021, PEV (BEV+ PHEV) constituted 43% of the new-car sales. The total stock of PEVs in Sweden was almost 297,600 vehicles (Swedish Transport Analysis).
The most influential policy to promote plug-in electric vehicle sales in Sweden is the EU's CO2 emission reduction targets for new vehicles. In 2021, the phase-in of the 2021 target of 95 g CO2/km contributed to a significant market share increase and plug-in electric vehicles now comprise 6% of all passenger cars. In 2021, there were three major national demand-side policies to promote the sales of plug-in electric vehicles in Sweden.

Bonus-malus scheme

The Swedish bonus-malus scheme was introduced in July 2018, and replaced a purchase rebate scheme. The bonus-malus scheme includes elements of decreasing the purchase cost of a vehicle, as well as the vehicle tax. In 2020, battery electric vehicles (BEVs) and fuel cell vehicles (FCV) were eligible for the maximum bonus, which is about 6,000 EUR. For plug-in electric vehicles (PHEVs), the bonus decreases linearly down to 60 g CO2/km (based on the WLTP).

The bonus-malus also includes light-duty vans, which were excluded in the previous purchase rebate scheme. The vehicle tax system was revised as the bonus-malus scheme was introduced. Previously, PEVs were tax-exempt in the first 5 years of ownership, but since July 2018 the tax exemption has been reduced to 3 years.
In 2021, the government changed the upper bonus threshold of the bonus-malus scheme from a maximum of 70 g CO2/km to 60 g CO2/km, and increased the bonus for BEVs and FCVs to about 7,000 EUR.

Reduced value of fringe benefits

For a long time, it has been advantageous to receive a car as part of the salary in Sweden. For electric vehicles, this benefit has been even better. This has meant that about 75% of the Swedish electric vehicles have been financed in this way, but there are still some sub-subscriptions for electric vehicles. This benefit has now been reduced in general, and in 2021 this has meant that there is a more even distribution between electric cars financed in this way and privately owned electric cars.

EV Bus/Trucks/Work Machines Rebate

In 2016, the Government introduced a purchase subsidy specifically targeting electric buses. Initially, only battery-electric, and plug-in hybrid buses could be granted a rebate. However, in 2017, fuel cell buses using renewable hydrogen were also included in the scheme. In 2018, the EV bus scheme further expanded to also grant private transport companies the purchase rebate. In 2019, the government decided to even include electric trucks and heavy equipment. In December 2021, 144 million EUR were allocated to the scheme for 2022, and 1 million EUR were earmarked for trucks and heavy equipment. The Swedish government also decided to increase the premium for electric buses from 10 to 20% of the purchase price.

Fleet Totals (as of December 31st 2021)

*Total including ICEVs

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	n.a	n.a	n.a	n.a	n.a
Electric moped (<50 kmph)	n.a	n.a	n.a	n.a	102 000
Auto-rickshaw	n.a	n.a	n.a	n.a	n.a
Motorcycle	338	n.a	n.a	n.a	312 987
Motorcycle with sidecar	n.a	n.a	n.a	n.a	n.a
Motorized tricycle	n.a	n.a	n.a	n.a	n.a
Passenger vehicles	110 177	152 738	189 498	n.a	4 986 750
Buses and Minibuses	662	n.a	n.a	n.a	13 594
Light Commercial vehicles	8 396	58	160	n.a	605 938
Medium and Heavy Weight Trucks	72	n.a	n.a	n.a	85 554

Total Sales 1st Jan 2021 to 31st Dec 2021

*Total including ICEVs

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike	n.a	n.a	n.a	n.a	n.a
Electric moped (<50 kmph)	n.a	n.a	n.a	n.a	n.a
Auto-rickshaw	n.a	n.a	n.a	n.a	n.a
Motorcycle	5 998	n.a	n.a	n.a	23 156
Motorcycle with sidecar	n.a	n.a	n.a	n.a	n.a
Motorized tricycle	n.a	n.a	n.a	n.a	n.a
Passenger vehicles	57 881	24 137	78 200	3	314 313
Buses and Minibuses	179	n.a	n.a	n.a	832
Light Commercial vehicles	2 707	135	56	n.a	36 238
Medium and Heavy Weight Trucks	48	14	1	1	5 304

CHARGING INFRASTRUCTURE OR EVSE

The Swedish electricity market is completely deregulated, which enables almost anyone to become a charging point operator (CPO). This has created a vast ecosystem of charging infrastructure, which benefits from both private and public efforts to deploy EVSE.

Klimatklivet – The Climate Leap

In September 2015, the Swedish government launched the investment support scheme Klimatklivet, the Climate Leap. As stated before, Klimatklivet is a general investment support scheme, not specifically aimed at charging infrastructure deployment, that grants up to 50% of a relevant investment cost. Klimatklivet has also granted support to charging stations for buses, trucks, airplanes, and boats.

Regional Electrification Pilots

The new support from the Swedish government that can go to charging infrastructure and tank infrastructure for hydrogen. It is, together with, among other things, the Climate Leap, part of the government's effort to accelerate the electrification of freight transport. Approximately EUR 100 million has been set aside for support for 2021-2022. However, no funds have been paid out for 2021, as there has been uncertainty in how the support regulations will be formulated in relation to the EU state aid rules.

Home-charging support scheme

TAX REDUCTION FOR GREEN TECHNOLOGY

From 1 January 2021, there is an opportunity to get a tax reduction for parts of the cost when a company is hired for the installation of green technology. Only work and materials entitle to a deduction. The deduction may not exceed 15 percent for the installation of solar cells and 50 percent for the installation of systems for storage of self-produced electricity or installation of a charging point for electric vehicles. It is possible to receive a maximum of SEK 50,000 in tax reduction for the installation of green technology per year. For 2021, EUR 49 million has been paid for the installation of almost 50,000 charging points.

Fast-charging stations along major routes

To complete a nation-wide fast-charging network, the government appointed 15 million EUR for 2020-2022. The Swedish Transport Administration estimates that 70-80 additional locations for fast charging are necessary to fulfil a national wide network. The first call opened in the autumn of 2020, where 21 identified locations along major public roads were subject to a reversed auction and 20 locations got tenders. In 2021, the second call comprised about 70 locations.

*As of December 31st 2022

Type of Public EVSE	Number of Charging Points*	Number of Locations*
AC Level 1 Chargers (≤3.7 kW)	3691	n.a
AC Level 2 Chargers (>3.7 kW, ≤22 kW)	8763	n.a
AC Fast Chargers (43 kW)	180	n.a
DC Fast Chargers (≤50 kW)	1040	n.a
Tesla Superchargers (DC >120kW - 250kW)	338	n.a
Ultrafast-High power chargers (DC >50 kW and ≤350 kW)	80	n.a
Inductive Chargers (EM charging)	2	n.a

EV DEMONSTRATION PROJECTS

UPSCALING OF REGIONAL ELECTRIFIED TRANSPORT FLOWS (REEL)

In the Reel project[5], which is now being scaled up, 40 battery-electric trucks will be used in a number of regional freight transport services. The vehicles will roll all over Sweden, but with concentration in Mälardalen, Skåne, and Västra Götaland. Both prototypes and mass-produced trucks with a total weight of 16-74 tons will be included. In addition, the project will include charging infrastructure with digitally connected system support at depots, logistics terminals and other important logistics points. The project brings together transport buyers, freight forwarders, and distributors, haulers, terminal operators, charging point operators, electricity network companies, as well as suppliers of trucks, charging equipment, and management systems. In addition, regions, cities, and universities participate in the project. The Reel project is now scaled up, and initial participating parities are Einride, Scania, and the Volvo Group, but more parties from business, regions, cities, and academia will be announced shortly. The program FFI finances with 8.5 million EUR, and the project partners contribute with 10 million EUR. The state authorities, The Swedish Energy Agency, the Swedish Transport Administration, and Vinnova, contribute funding, case expertise, system perspectives, and synchronization of R&I support and infrastructure measures. The project is led by the national collaboration platform for transport efficiency, CLOSER by Lindholmen Science Park. The project has started and will run until 2024.

Figure 1: Einride truck in project Reel

SYSTEM SOLUTIONS FOR LONG-DISTANCE TRANSPORTATION WITH BATTERY-ELECTRIC VEHICLES (E-CHARGE)

The E-Charge project develops battery-electric prototype trucks that can handle the really long-distance transports, i.e., daily driving distances longer than 50 km. The vehicles are then tested in a couple of large logistics flows between our largest cities, and are charged with high-power charging in connection with the driver's rest periods. The project combines development work in several thematic areas with research at an integrated system level to build knowledge and understanding of how electrification of long-distance transportation can affect larger systems, such as logistics and electrical systems.

In the project, even the largest trucks will be run on electricity, which just a few years ago was basically considered completely impossible. This shows how fast the development is towards fossil freedom in the transport area. In the project, Scania and the Volvo Group collaborate with ABB, Circle K, and OKQ8. The project also involves ICA Sverige AB, DB Schenker, Tommy Nordbergh Åkeri, Vattenfall, and other energy companies and electricity network owners. Swedish Electromobility Centre (SEC) is an external research partner, and Lindholmen Science Park coordinates the project. The program FFI finances with SEK 10 million EUR and the project partners contribute with 11 million EUR. The project has started and will run until 2024.

ELECTRIC ROAD SYSTEMS

The Swedish Transport Administration in July 2021 decided that Sweden's first permanent electric road will be built on the E20 between Hallsberg and Örebro. Procurement and choice of technology are now underway. The electric road is expected to be completed as early as 2025. The route is a total of about 21 km long, with two lanes in each direction.

OUTLOOK

The development of the market share for plug-in electric passenger cars, city buses, and distribution trucks looks very positive in Sweden. One major driver for this development is the EU CO2 reduction requirements for new vehicles. The Swedish policy framework has accomplished a high allocation compared to other EU markets. Future developments in Sweden depend on Swedish policy frameworks, as well as other EU countries, which could influence the allocation of vehicles to Sweden. Major efforts are now being made to enable public fast charging for heavy vehicles. Continuous charging, so-called electric roads systems, are being explored more widely on public roads.

References

[1] Joint venture agreement charging network | TRATON

[2] Chalmers University of Technology | Chalmers

[3] Swedish research creating sustainable growth | RISE

[4] Building a European battery industry - European Battery Alliance (eba250.com)

[5] REEL | Closer (lindholmen.se)

Switzerland

MAJOR DEVELOPMENTS IN 2021

Following the record low car sales in 2020, there was a slight increase in car registrations in 2021. Total sales are still 22% below pre-pandemic levels. A major reason for the low sales in 2021 were global supply chain issues, particularly the shortage of microchips, which led to delivery delays and dealers unable to meet the market demand.

The strong trend towards an increased share of alternative drives was confirmed in 2021 with a new all-time sales record of BEVs and PHEVs. Cars with alternative drives are strongly advertised, and dealers are incentivized to give preference to EVs, in order to reduce the average CO2 footprint of vehicles sold. In such ways, the penalties stipulated by Swiss law for exceeding the CO2 target for importers could be reduced or avoided.

Electric vehicles on the Swiss market

Due to the high number of sales in the fourth quarter, the share of BEV car registrations (13.3%) was finally almost identical to the proportion of diesel vehicles (13.6%). The continuous increase exceeds targets and expectations. This is notable, as Switzerland provides no national purchase incentives and only modest support at cantonal level, mainly through reduced or no vehicle registration tax.

It is also remarkable that the general trend is towards BEV (13.3% market share in 2021), with PHEV sales increasing at a slower pace (9.1% market share). As of December 31, a little more than 86 000 purely electric passenger cars were on the road in Switzerland, representing 1.7% of the total number of vehicles (PHEV: 1.0%).

Recent developments in the regulatory framework

RIGHT TO CHARGE AT HOME

Switzerland has a high share of tenants compared to homeowners. The availability of charging options at home is thus a widespread issue and is currently one of the major reasons to decide against electric when buying a new car. The federal parliament is currently discussing the legal basis for a right to a charging station for electric vehicles.

TOTAL REVISION OF CO2 ACT REJECTED AT THE BALLOT BOX

In September 2020, the Swiss parliament passed the CO2 Act, which outlined the framework to reach net-zero in 2050 and for fulfilling the obligations associated with the Paris Agreement. A referendum was held in June 2021, and the revision was rejected by 51.6% of the voters.

A new revision is currently under consultation, still including support for recharging stations. It will come into force in 2024 at the earliest.

FURTHER INCENTIVES

Some cantons and municipalities propose tax incentives or even subsidies to alternative energy vehicles and charging infrastructure. These grants are often rather modest. The federal and cantonal administrations are also working on the removal of obstacles and regulatory hurdles in the planning, installation, and operation of charging stations.

Energy perspectives 2050+: detailed scenarios published

The Swiss Energy Perspectives 2050+ present scenarios how Switzerland's energy system can ensure secure supply and reach net-zero greenhouse gas emissions by 2050. In 2021, more detailed scenario results were published.[1]

Electromobility roadmap 2022

In late 2018, key representatives from the automotive, energy and real estate sectors, as well as members of the federal government, cantons, cities, and municipalities, signed the electromobility roadmap[2] Together, they have committed to working on concrete measures favourable to the development of electromobility. The first step was to reach 15% of BEV and PHEV cars among new registrations by 2022. This goal has already been surpassed by far, with more than 22% of BEV + PHEV among new registrations as of 31 December 2021.

NEW OBJECTIVES

Achieving the 2022 targets ahead of schedule prompted the roadmap community to define more ambitious goals for 2025. An intense collaborative process has been conducted throughout the year. In an intense collaborative process, the major national umbrella associations impacted by the transition towards electromobility, the main players of the different industries concerned, as well as leading government representatives, including Federal Councillor Simonetta Sommaruga, developed a common understanding of the next challenges to be addressed to further accelerate the adoption of electromobility. As a result, the following 3 sub-targets were identified: (i) 50% BEV+PHEV in new car registrations by 2025, (ii) 20,000 publicly accessible charging stations and (iii) easy and grid-friendly charging at home, at work and on the way. All the organizations involved in the Roadmap are expected to formally endorse the new 2025 targets at a summit in May 2022. In the meantime, more than 60 new measures in line with the new objectives have been submitted to the Roadmap.

Figure 1: Federal Councillor Simonetta Sommaruga spoke via video conference to various national stakeholders involved in the Roadmap, in order to motivate them personally to commit to electromobility.

HEVS, PHEVS, AND EVS ON THE ROAD

In 2021, 350,056 motor vehicles (including among others agricultural and industrial vehicles, but without mopeds) were newly registered in Switzerland. This is an increase of 3.9% compared to 2020, but still 14.6% below the 2019 pre-pandemic level.

New passenger car registrations increased by 3.2% in 2021 compared to 2020. Once again, the number of new electric cars rose sharply (+62.1% BEV and +50.9% PHEV). Together, these two groups accounted for 22% of all new passenger car sales in 2021.

In addition to cars, lightweight vehicles, most notably bikes and electric bikes, again reached record sales in 2021.

n.a. = not available

a Pedelecs with power assist up to 25 km/h

b UNECE categories L1 (Moped capable of max 50 km/h with an engine less than 50cc)

c UNECE categories L2

d UNECE categories L3

e UNECE categories L4

f UNECE categories L5

g UNECE categories M1

h UNECE categories M2-M3

i UNECE categories N1

j UNECE categories N2-N3

*Total including ICEVs

Fleet Totals (as of December 31st 2021)

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike [a]	n.a.	n.a.	n.a.	n.a.	n.a.
Electric moped (<50 kmph) [b]	3 857	0	0	0	18 266
Auto-rickshaw [c]	7 393	1	0	0	7 713
Motorcycle [d]	3 694	48	0	0	691 006
Motorcycle with sidecar [e]	0	0	0	0	3 031
Motorized tricycle [f]	235	0	0	0	4 148
Passenger vehicles [g]	86 442	185 061	53 098	158	4 802 973
Buses and Minibuses [h]	166	668	0	2	14 040
Light Commercial vehicles [i]	3 993	300	1	0	428 855
Medium and Heavy Weight Trucks [j]	154	18	0	52	60 830

Total Sales 1st Jan 2021 to 31st Dec 2021

Vehicle Type	EVs	HEVs	PHEVs	FCVs	TOTAL*
Electric bike [a]	164648	0	0	0	0
Electric moped (<50 kmph) [b]	1011	0	0	0	1 375
Auto-rickshaw [c]	499	0	0	0	522
Motorcycle [d]	1 020	0	0	0	51 717
Motorcycle with sidecar [e]	0	0	0	0	52
Motorized tricycle [f]	7	0	0	0	322
Passenger vehicles [g]	31 583	51 942	21 640	66	244 390
Buses and Minibuses [h]	60	214	0	0	812
Light Commercial vehicles [i]	1 523	106	0	0	29 745
Medium and Heavy Weight Trucks [j]	80	0	0	33	3 826

Quarterly updated information on new registrations of vehicles with alternative drives can be found on the website of the Swiss Federal Office of Energy: www.bfe.admin.ch/bfe/en/home/supply/statistics-and-geodata/key-data-for-vehicles/key-data-relating-to-alternative-drives.html.

CHARGING INFRASTRUCTURE OR EVSE

Electric charging

As of 31 December 2021, there were 3,377 locations in Switzerland with 6,606 publicly accessible charging stations, representing a total of about 10,000 active plugs. Around 8% of them deliver more than 100kW.

A fifth of the 100 federally owned motorway rest areas have been electrified. By 2030, at the latest, at least four charging slots will be available at each rest area. In order to achieve this goal, five operators were selected in a public tender to operate 20 rest areas each. High-power grid infrastructure will be pre-financed by the federal government, and then charged to the operators over a period of 30 years. The cantonal rest areas are also gradually being equipped.

*As of December 31st 2021
Since some charging stations are not fully characterized in the databases, this table was partially completed by applying a statistical method.

** There are 1 138 plugs with max 3.7kW. However, they are often connected to a charging station that is also capable of supplying 22 kW in Type 2. Only 30 locations offer only 3.7kW.

Type of Public EVSE	Number of Charging Points*	Number of Locations*
AC Level 1 Chargers (≤3.7 kW)	1 138	30**
AC Level 2 Chargers (>3.7 kW, ≤22 kW)	6 805	2 674
AC Fast Chargers (43 kW)	252	98
DC Fast Chargers (≤50 kW)	928	333
Tesla Superchargers (DC >120kW - 250kW)	500	22
Ultrafast-High power chargers (DC >50 kW and ≤350 kW)	587	220
Inductive Chargers (EM charging)	n.a.	n.a

H2 mobility

Green hydrogen is locally produced from 100% renewable hydroelectricity. As of January 2022, hydrogen is available at 10 public filling stations in Switzerland, supplying around 50 H2 trucks in regular service on Swiss roads.

Trucks with alternative drives (H2 FC and BEV) are promoted through the exemption of the heavy goods traffic tax.

Figure 2: A hydrogen truck used on a daily basis by a major Swiss retailer (Picture courtesy of Genossenschaft Migros Ostschweiz).

EV DEMONSTRATION PROJECTS AND INNOVATION

Research and development towards electrification and defossilization of the transport sector in Switzerland takes place at federal research institutions, universities and in the private sector. With its Mobility Research and Pilot and Demonstration Programmes, the Federal Office of Energy is a key funder of such activities. Some noteworthy examples are presented here.

Vehicle-grid integration - V2X

The fast growth of electric mobility has a major impact on the electric grid. A seamless and grid-friendly integration is of utmost importance for the Federal Office of Energy. It thus supports a number of V2X projects.

The project in the Erlenmatt Ost[3] in Basel was completed in 2021 after three years. The area is organized as a self-consumption community with a 580 kW photovoltaic (PV) system and local district heating. Residents have access to shared electric cars (Nissan Leaf and e-NV200) that are connected to the grid via a bidirectional charging station. It could be demonstrated that even only two such cars could significantly reduce peak loads (peak-shaving) and increase the area's own consumption.

The project also showed how V2X can readily be integrated into the energy management system of the buildings and area, and even how this could be operated in a car-sharing mode.

Figure 3: One of the electric vehicles available for car-sharing in Erlenmatt ost. The bidirectional charging station enables V2X functionality and grid-friendly charging.

This early pilot project is now followed by a number of larger demonstration and other research projects:

Within V2X Suisse[4], Switzerland's main car-sharing operator Mobility in cooperation with Honda and other industry partners launched the first mass-deployment of the COMBO-CCS configuration with bi-directional functionality. Until fall 2022, 50 bidirectional electric vehicles will be added to the fleet and used grid friendly. The aggregated flexibility will be made available to SwissGrid (Switzerland's TSO) for primary frequency stabilization. The demonstration project is accompanied by a number of research projects focusing on specific aspects, such as data protocols and communication between car, fleet operator, charging station, flexibility aggregator and TSO/DSO, as well as an efficient combination of fleet management and V2X functionality.

Another demonstration project, Sunny arc,[5] examines the synergies between local renewable energy generation and electromobility. Up to 1500 kW PV are going to be combined with up to 250 charging stations (50 bidirectional) in the microgrid supplying the technology park Y-PARC in Yverdon-les-Bains. Smart charging and dynamic tariffs are deployed to evaluate the potential of V2X to increase self-consumption and stabilize the Swiss grid.

H2 + Electric-Trucks

In 2021, Swiss e-truck manufacturer Futuricum broke the record for the longest distance driven by an electric truck without intermediate charging. In total, the project team covered 1 099 kilometres in 23 hours. The 19-ton, 680-horsepower truck was equipped with a 680-kilowatt-hour battery.

Electric passenger boats

Many passenger ships are operating on Swiss lakes. In 2021, several boat companies have started their transition to 100% battery electric boats and hybridization. The Swiss Confederation has subsidized a series of projects, ranging from retrofitting existing passenger boats, for example on Lake Lugano, to integrating the latest generation of electric boats into the regular schedule on Lake Geneva. These projects include issues related to safety and charging stations.[6]

Battery / Battery Recycling

Battery technologies and their recycling have gained importance in recent years. The new iBat association[7], which brings together players of the academic community and the industry, promotes innovation projects and dissemination of information in Switzerland, while representing the sector at national and international level.

Leveraging the potential trolleybus lines

As part of the gradual electrification of diesel bus lines, Switzerland takes advantage of its many trolleybus lines, which can now be easily extended without adding infrastructure, simply by replacing the vehicles with battery-equipped versions. Many cities, such as Berne, Biel-Bienne, La Chaux-de-Fonds, and Zurich, have replaced or are in the process of replacing diesel buses with battery trolleybuses. The latter use opportunity charging with their pantographs as they pass the electricity lines in the city centres. They then continue their journey in the surrounding areas using their battery.

The Swiss manufacturer HESS has specialised in this technology and has carried out numerous innovative projects, notably with the ETH.

Figure 4: Hess lightTram 19 DC on VBSG line 6, in battery operation, at the station Post St. Georgen with lowered pantographs (Picture courtesy of EtschPat, via Wikimedia Commons).

OUTLOOK

With 2,126 newly registered BEVs in January 2022, sales have doubled compared to the same month in the previous year.

The key stakeholders mostly affected (positively or negatively) by electromobility are now all convinced that its development will be fast. Many of them have contributed to the acceleration of the movement by setting ambitious targets to the national Electromobility Roadmap.

One of the main challenges remains the development of the charging infrastructure, especially at home and at work. Obstacles to the installation of charging stations are identified, and initiatives are pursued at both stakeholder and policy level to reduce them.

The latest projections published in June 2021[8] by the Swiss electromobility umbrella organization (Swiss eMobility) indicate that by 2030, between 72% and 94% of new passenger cars registrations should be BEV or PHEV, with around 1.5 million in circulation (about a third of the total fleet).

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United Kingdom

MAJOR DEVELOPMENTS IN 2021

In 2019, transport produced 27% of the UK's total emissions. Of this, the majority (91%) came from road transport vehicles. The biggest contributors to this were cars and taxis, which made up 61% of the emissions from road transport, followed by 18% from Heavy Goods Vehicles (HGVs) and 17% from vans.[1]

In November 2020, the UK was the first G7 country to announce ambitious phase out dates for petrol and diesel cars and vans by 2030, and from 2035, all new cars and vans must be zero emissions at the tailpipe. Phasing out the sale of new petrol and diesel cars and vans by 2035 will reduce greenhouse gas emissions faster, with savings equivalent to almost five million fewer cars on the road each year by 2035.

2021 was an important year for the UK Government, achieving several milestones in becoming a net zero economy by 2050. It is going further and faster to decarbonise transport, launching a host of policies and laying legislations essential to achieve zero emission transport, as well as its wider goal of decarbonisation.

The phase out announcement was followed by the Office for Zero Emission Vehicles' (OZEV) 2035 Delivery Plan[2] in July 2021, which brings together all committed funding streams and measures for decarbonising cars and vans, from across the Government, into a single document. It sets out significant milestones towards our phase out dates for petrol and diesel cars and vans. Alongside this, the Department for Transport's (DfT) ground-breaking Transport Decarbonisation Plan (TDP)[3] was also published.

This plan sets out the Government's commitments and the actions needed to decarbonise the entire transport systems in the UK. It includes our pathway to net zero transport, the wider benefits this can deliver, and the principles that underpin our approach. As part of the TDP, the UK Government increased its level of ambition on its own vehicle fleet electrification and committed to 100% of the Government car and van fleet to be fully zero emission at the tailpipe by 31 December 2027.

As part of the Net Zero Strategy,[4] in October 2021, the Government announced that it will introduce a zero-emission vehicle (ZEV) mandate, which will set targets for a percentage of manufacturer's new car and van sales to be zero emissions each year, starting in 2024. This will deliver on our 2030 and 2035 phase out dates and support interim carbon budgets. The Government will bring forward specific proposals for the future regulation that is to apply to our new vehicle fleet. These will be the subject of future detailed consultations with all stakeholders.

Also, as one of the new Glasgow Breakthroughs launched by the Prime Minister at the COP26 World Leaders Summit,[5] 30 countries have agreed to work together to make ZEVs the new normal by making them accessible, affordable, and sustainable in all regions by 2030 or sooner. In addition, on Transport Day, a group of ministers and industry leaders signed a joint declaration to commit to work towards 100% zero emission new car and van sales by 2040, and by no later than 2035 in leading markets.[6]

Furthering its commitment to net zero transport, in November 2021, the UK Government announced that a phase out date for the sale of new, non-zero emission HGVs less than or equal to 26 tonnes will be introduced from 2035. From 2040, all new HGVs must be fully zero emission at the tailpipe.[7]

State of the market – progress to date

The uptake of electric vehicles (EVs) in the UK continued an upward trajectory in 2021, showing that over one in six new cars sold in the country had a plug, with 11.6% being battery electric vehicles (BEVs) and 7.0% plug-in hybrid electric vehicles (PHEVs), up from 6.6% for BEVs and 4.1% for PHEVs in 2020.

An ACEA analysis of registration data in 2021 revealed that the UK is the second most popular country in Europe for battery electric cars[8] and a front-runner for battery electric vans.[9] We note some concern around the supply of vehicles, and we will be working with the sector to ensure consumers and businesses wanting to switch can do so easily and with confidence.

Figures 1 and 2 depict the increase in uptake of battery electric cars and vans and plug-in electric cars and vans between Q3 2016 and Q3 2021.

Figure 1: New car registrations – quarterly

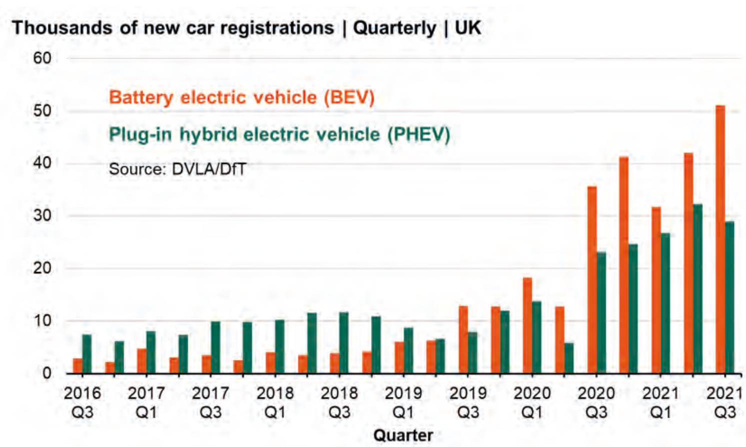
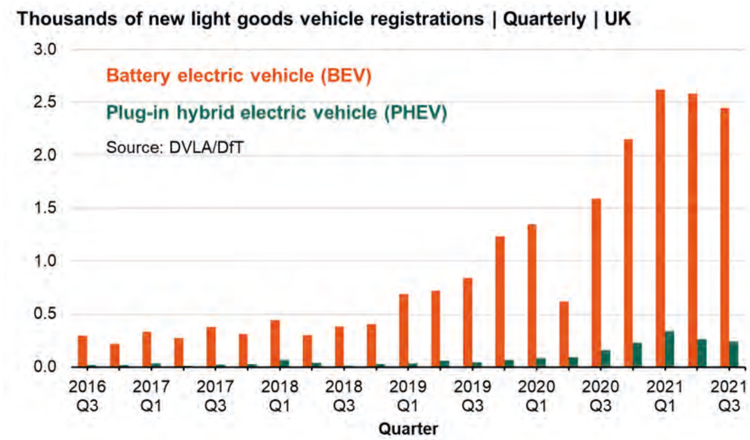


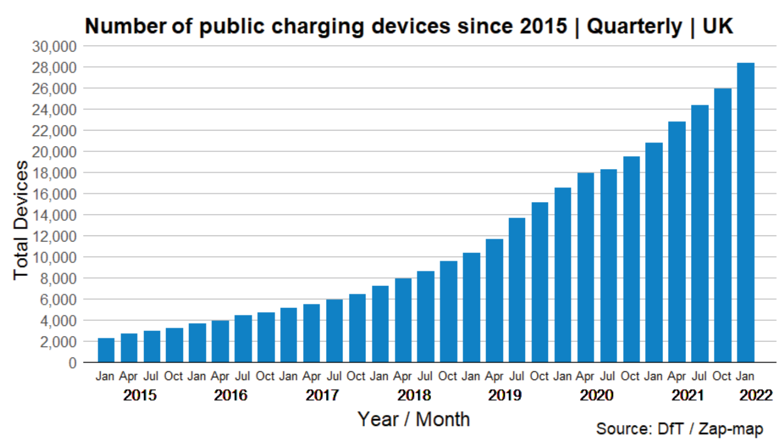
Figure 2: New LGV registrations – quarterly



The UK network of EV chargepoints is growing. The UK Government and industry have supported the installation of over 29,500 publicly available charging devices, including more than 5,400 rapid devices – one of the largest networks in Europe. In 2021, we witnessed the total number of public chargepoints increase by 37%, whilst rapid chargepoint numbers increased by 33%.[10] On average, over 600 new chargers are being added to the UK's road network each month. In addition to public chargepoints, Government has supported the installation of over 300,000 chargepoints in homes and businesses.

Figure 3 shows the increase in number of EV chargepoint installations between 2015-2021.

Figure 3: Chargepoint installations



Policy initiatives

During 2020-21, the UK has taken a number of steps to increase the uptake of ultra-low emission vehicles (ULEVs) and ZEVs, support innovation in ZEV technology, and create a fit for purpose charging infrastructure network.

Government has committed £2.5 billion since 2020 to support the transition to ZEVs, with funding to offset their higher upfront cost, and to accelerate the rollout of chargepoint infrastructure.

PLUG-IN VEHICLE GRANTS

Government grants have been in place for over a decade to help reduce the up-front purchase price of EVs. Since 2011, the plug-in vehicle grants have supported over 430,000 ULEVs, of which over 290,000 are ZEVs.

We are refocusing our vehicle grants on the more affordable ZEVs, where most consumers will be looking and where taxpayers' money will make more of a difference. Grants are only one way in which the UK Government provides support to ZEVs. Generous tax incentives are also in place, including favourable company car tax rates, which can save drivers over £2000 a year and remains a significant driver of sales. We also continue to offer zero road tax (new and used cars under £40,000) and zero van benefit charge.

To recognise the additional challenges Wheelchair Accessible Vehicles (WAVs) face in transitioning to zero emissions, we are offering a higher grant rate of up £2,500 through our Plug-in Car Grant scheme for these vehicles.

EV INFRASTRUCTURE INVESTMENT

Government is providing grants for homeowners, businesses, and local authorities (LAs) to install chargepoints and is also supporting the deployment of rapid chargepoints. The Government will provide over £1.6 billion over the next four years to support the continued roll-out of chargepoints on motorways and major A roads, in homes and businesses and on-street.

Government's policy initiatives to support the rollout of EV infrastructure are detailed in section 3 below.

Other initiatives

SUPPORT FOR LOCAL AUTHORITIES (LAS)

We will publish an EV infrastructure guide for LAs that we have developed with the Institution of Engineering and Technology (IET). The TDP committed Government to producing a range of decarbonisation 'toolkits' to support LAs in their plans and policies to reduce carbon emissions from transport. These will be published shortly and include guidance on e-car clubs, LA fleet electrification, and EV infrastructure. As part of our £400 million Local EV Infrastructure (LEVI) fund, we will provide £50 million of resource funding to support LAs plan for and support the delivery of local EV charging infrastructure in their areas. This fund will help establish a lasting legacy of capacity and effectiveness within LAs across the country.

ZERO EMISSION BUSES

In its National Bus Strategy in March 2021, the UK Government committed to supporting the introduction of 4,000 zero emission buses (ZEBs) and achieving an all-ZEB fleet.[11] We are providing over £525 million funding for ZEBs this Parliament. The Government announced the first areas to be awarded funding from the Zero Emission Bus Regional Areas (ZEBRA) scheme fast track in October 2021. A second group of local transport authorities will be submitting proposals to secure funding through the standard process of the scheme. Funding will be awarded to successful areas in Spring 2022.

In March 2022, the Government launched a public consultation seeking views on setting a specific date between 2025 and 2032 for ending the sale of new non-zero emission buses.[12] This means that, from 2032 at the latest, any new buses sold across the UK would need to be fully zero-emission at the tail pipe. Such a move would bolster the market for ZEBs, making them the default choice for operators to transition sooner.

HGV DECARBONISATION TRIALS

The UK Government recognises the need to support industry in making this transition. We will build on the success of our £20 million zero emission road freight trials by trialling three zero emission HGV technologies at scale on UK roads. Trials will determine the operational benefits and infrastructure needs of these technologies, and support UK industry to develop cost-effective, zero-emission HGVs and their refuelling infrastructure in the UK.

CHARGEPOINT DESIGN PROJECT

In November 2021, the UK Government unveiled a new design for EV chargepoints, which could be as iconic as the Great British post box, London bus or black cab[13]. It was showcased in the UK Pavilion at COP26 and designed together with the Royal College of Art and PA Consulting to develop a user-centric chargepoint concept design, prioritising ease of use and inclusivity. The concept raises awareness and generates excitement of our EV programme.

GREEN NUMBER PLATES

In December 2020, the UK Government introduced green number plates for ZEVs.[14] Green number plates help LAs design and plan local policies and incentives, such as cheaper or free parking for EVs or zero emission zones.

CHARGING INFRASTRUCTURE OR EVSE

As the sale of plug-in vehicles continues to soar, the UK Government has published a landmark EV infrastructure strategy, setting out our plans to accelerate the rollout of a world-class charging network. Our strategy sets out our vision and commitments to make EV charging cheaper and more convenient than refuelling at a petrol station. Of the £2.5 billion of Government funding committed to the EV transition since 2020, over £1.6 billion will be used to support charging infrastructure.[15]

We have announced new regulations for public chargepoints to improve confidence in the charging network and make the user experience truly seamless. Drivers will benefit from easier payment methods, as well as the ability to compare prices and access real-time information about chargepoints. Chargepoints will need to be highly reliable and will need to have open data so that they are easy to find using maps and apps.[16]

Government also plans to support people to charge their cars at home by ensuring new homes are EV ready. The Government introduced legislation in December 2021, which requires new buildings to have a chargepoint or cable routes where there is associated parking.[17] This will lead to the installation of up to 145,000 new chargepoints across England every year.

Government is working on several measures to ensure a smarter, more flexible energy system is realised, including mandating that all new private chargepoints sold in Great Britain must have smart functionality. In December 2021, the EV Smart Charging Regulations were made into law.[18] This technology will reduce energy bills for all consumers relative to a system without this source of flexibility. It also makes more effective use of intermittent renewable energy sources, reducing the carbon footprint of the energy powering the grid.

The On-Street Residential Chargepoint Scheme (ORCS) is available to LAs across the UK and provides funding towards the installation of public EV charging infrastructure for those without private parking. DfT statistics show that ORCS has supported 75 different LAs to install over 2,000 chargepoints. A further 88 local authorities have also been awarded grant funding, providing more than 4,500 on-street public chargepoints with their installation yet to be completed.[19] £20 million was made available in the financial year 2021-22, and an equal amount of funding is expected to continue in the financial year 2022-23.

Government provides a grant of up to £350 towards the installation of domestic chargers under the Electric Vehicle Homecharge Scheme (EVHS). To date, over 277,000 domestic chargepoint installations have benefitted from these grants.[20] In 2022, EVHS will be reformed to provide additional help for people living in rented and leasehold accommodation (flats). Not only will people living in such accommodation be able to apply, but in 2022 their landlords or building owners will also be able to. Additional support will also be available to help install chargepoints in the parking of apartment blocks.

Through the Workplace Charging Scheme (WCS), businesses, charities, and the wider public sector can get grants of up to £350 per socket for installing up to 40 charging sockets for their employees and fleets. So far, over 22,000 installations have been funded using the scheme.[21] In 2022, WCS will be opened to small accommodation business and the charity sector. This will help to accelerate EV uptake in rural areas and support the UK tourist industry. Additional help will also be provided to Small and Medium Sized Enterprises to provision their staff or fleet carparks.
3.1 Supporting the development of rapid charging infrastructure

The rollout of rapid charging is an opportunity to remove range anxiety for EV drivers across the roads network, and it is vital that the UK's motorways and strategic roads are appropriately equipped for mass EV uptake and meet the needs of drivers for use when they are undertaking longer journeys. With support from the Government and private sector investment, today, a driver is never more than 25 miles away from a rapid chargepoint anywhere along England's motorways and major-A roads.

In May 2020, we published an ambitious vision for rapid charging infrastructure along strategic roads in England over the next decade. This vision sets out the number of rapid chargepoints that will be located across motorways and major A-roads to meet the future demand for EVs. Our £950 million rapid charging fund will support the rollout of at least 6,000 high powered chargepoints across England's motorways and major A-roads by 2035.

We are also working with the Office of Gas and Electricity Markets (Ofgem) to ensure that charging a vehicle is completely integrated with our smart energy system. This will deliver benefits to the grid and lower cost electricity tariffs for those willing to charge flexibly.

So far, the £400 million Charging Infrastructure Investment Fund (CIIF), a joint Government – industry fund which makes investments on a commercial basis, has made four investments which will create 5,000 more rapid chargepoints across the

UK and increase provision of on-street residential chargepoints for those without access to private driveways.

EV RESEARCH, DEVELOPMENT AND DEMONSTRATION PROJECTS

OZEV has funded over 100 projects, advancing technologies for ZEVs and accompanying infrastructure.

In 2021, we provided £20 million to 62 ZEV innovation projects. Some of the winning projects include the development of a: solar-powered refrigeration unit for commercial vehicles; onboard plug-in device that provides drivers with data on battery health to improve the experience of buying second-hand EVs; kinetic battery that will provide a temporary power boost for charging the next generation of ultra-fast EVs at peak times in rural areas.

The UK has significant capability for automotive innovation, providing vital technology development and accompanying infrastructure for ZEVs. We want the UK to be leading not only in the design and manufacture of ZEVs, but also associated technologies, such as on-street and wireless charging and vehicle-to-X (V2X) technology.

In 2019, OZEV provided £30 million to projects delivering low-cost, scalable charging solutions. One of the leading projects includes the UK's first solar electric forecourt in Braintree, Essex, that opened in December 2020.[22] The project has paved the way for the lead participant Gridserve to announce plans of up to 100 similar electric forecourts across the country over the next 5 years. Other projects include trials of lamppost charging and pop-up chargers to reduce street clutter.

UK's first Electric Forecourt® near Braintree, Essex

In January 2020, the UK Transport Secretary announced that £3.4 million will be invested in trials for wireless charging of electric taxis in Nottingham. This technology could make it more convenient than ever to charge vehicles and could reduce cable clutter on streets.[23]

Vehicle-to-X (V2X, where X could represent the home, a building, or the grid) is an emerging technology enabling the export of energy from an EV battery. There are trials worldwide involving hundreds of vehicles, but it is not yet at mass deployment. In July 2021, the Department for Business, Energy, and Industrial Strategy (BEIS) published a Call for Evidence, seeking views on the potential role of V2X, and the barriers preventing this. The Call for Evidence closed in October 2021, and feedback from it will help inform Government's next steps to facilitate this source of flexibility. BEIS intends to publish a response in 2022.[24]

In March 2022, BEIS launched a £11.4 million V2X Innovation Programme to address barriers to this technology, including hardware cost and a lack of business models for a variety of consumers. Phase 1 (£2 million) will support the development of V2X bi-directional charging prototype hardware, software, or business models, in 12-month projects beginning in September 2022. We anticipate launching a Phase 2 competition supporting small scale V2X demonstrations in 2023.[25]

OUTLOOK

We will remove charging infrastructure as both a perceived and a real barrier to the adoption of EVs. EV charging should be cheaper and more convenient than refuelling at a petrol station. Specific predictions of the future mix and number of chargepoints are inherently uncertain in 2022 due to rapid developments in battery and charging technology, and because consumer preferences about where and when they would like to charge are still being revealed.

The commercial landscape for charging infrastructure is also developing quickly but the balance between fewer, higher-powered chargers and more numerous, lower-powered ones is not yet clear. By 2030, we expect there to be around 300,000 public chargepoints as a minimum in the UK, but there could potentially be more than double that number.

In any scenario, rollout must progress at pace to provide sufficient chargepoints ahead of demand and to ensure that the UK is a place where:

- Everyone can find and access reliable public chargepoints wherever they live.
- Effortless on and off-street charging for private and commercial drivers.
- Fairly priced and inclusively designed public charging.
- Market-led rollout for the majority of chargepoints.
- Infrastructure is seamlessly integrated into a smart energy system.
- Continued innovation to meet drivers' needs.

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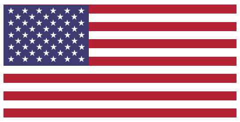


United States of America

MAJOR DEVELOPMENTS IN 2021

The United States (U.S.) population continues to rely on vehicles for personal transportation. Although, because of the continuing global COVID-19 pandemic, individuals continued to drive less than prior years, there was improvement from 2020. The cumulative national vehicle miles traveled (VMT) for the year 2021 was 2,960.3 billion vehicle miles (data available till the end of November 2021), which represents an increase of 11.2% (298.1 billion vehicle miles) compared to the prior year[1].

Sales of electric-drive vehicles in the U.S. in 2021 saw a rapid rebound and increased nearly 98% from their 2020 value (~607,567 in 2021 compared to ~307,589 in 2020), the cumulative total reached 2.32 million plug-in electric vehicles (PEVs) using December 2010 as the base. During 2021, there were 66 PEV models sold, including both plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs); as well as 38 hybrid electric vehicle (HEV) models, for total sales of ~1,407,900 units.[2]

Industry and Market

MARKET DEVELOPMENTS

- Volkswagen of America unveiled its Network Readiness Co-Op Program to help its dealership network establish the underlying EV infrastructure.[3]
- 13 additional U.S. EV plants have been announced and are expected to be operational within the next 5 years. Eight are joint ventures between automakers and battery manufacturers.[4]
- GM and POSCO Chemical will form a JV to construct a North American factory for critical EV battery materials.[5]
- Cummins signed an agreement with Sion Power to develop Li-metal.[6]

BATTERY TECHNOLOGY

- Xiaomi announced its high-silicon cell technology will deliver 5.5Ah vs the current tech's 5.0Ah.[7]
- Mercedes-Benz and Stellantis announced agreements with Factorial Energy to help develop solid-state batteries for EVs.[8]

CHARGING INFRASTRUCTURE

- Electrify America installed onsite, behind-the-meter battery energy storage systems at more than 140 ultra-fast DC charging stations around the U.S. with more than 30MW of capacity.[9]

Policy and Government

FEDERAL GOVERNMENT

- The U.S. passed a $1 trillion Bipartisan Infrastructure Law (BIL) bill to rebuild the country's aging public works system, fund new climate resilience initiatives, and expand access to high-speed internet service.[10] BIL authorizes a nationwide network of charging stations and $5B for states to build them.

- The Department of Energy (DOE) and Department of Transportation (DOT) Secretaries signed an MOU to create a Joint Office of Energy and Transportation to support the deployment of $7.5B from BIL. The Joint Office will help to accelerate deployment of a national network of charging stations and provide technical assistance to States and localities to build EV charging stations and other infrastructure.[11]

- DOE announced $209M in funding for 26 new lab projects focusing on EVs, advanced batteries and connected vehicles.[12]

- The Federal Consortium for Advanced Batteries (FCAB) released the Pre-application Battery Test Manual, which defines a series of tests to characterize performance and life behavior for advanced batteries. In developing this manual, multiple federal agencies worked in unison in support of the emerging domestic battery ecosystem.[13]

STATE AND LOCAL GOVERNMENTS

- New York City to invest $420M in EVs and infrastructure; all-electric fleet by 2035. [14]

- The California Energy Commission (CEC) released a solicitation for projects to improve and increase direct recycling of Li-ion batteries. [15]

HEVS, PHEVS AND EVS ON THE ROAD

This section provides the number of hybrid and electric vehicles on the road in the U.S. at the end of 2021. It also includes a price overview of the most popular-selling hybrid and electric vehicles. Figure 1 illustrates cumulative sales for HEVs, BEVs, and PHEVs over January – December 2021. It is observed that all three curves show a steady rise throughout the year.

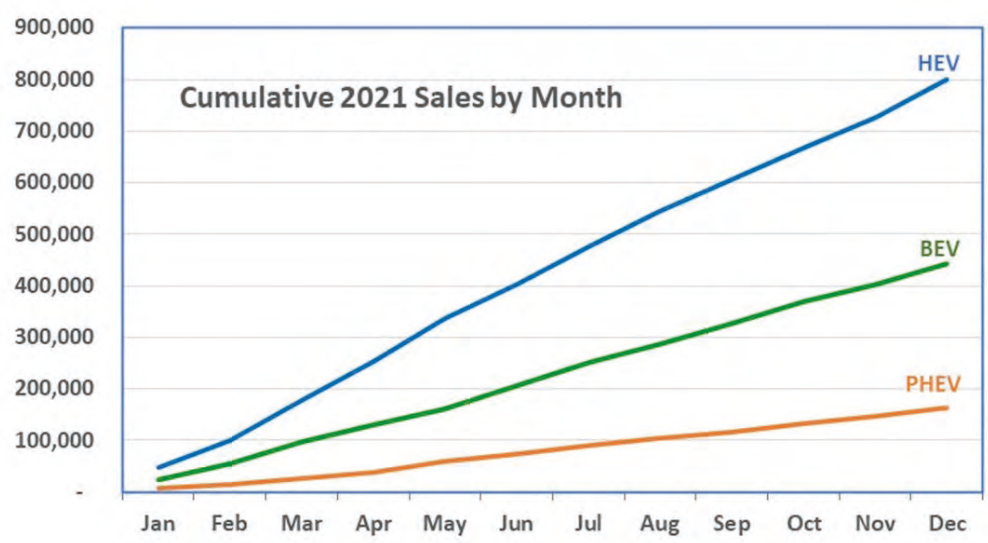


Figure 1: Cumulative sales of electrified vehicles in 2021, not including FCEVs. (Data source: Argonne National Laboratory)

Figure 2 shows the 2021 sales for the U.S. EV market leaders. It is observed that 2021 HEV sales increased 76% to 800,381 in 2021[16] from 454,890 in 2020.

There were 36 different models sold across the top 6 manufacturers. The top-selling models include Toyota RAV4, Toyota Sienna, Toyota Highlander, Toyota Venza, Honda CR-V Hybrid, Toyota Camry, Ford F Series, and Toyota Prius, which together accounted for 67% of the U.S. HEV market. The Toyota Prius lineup, once dominant in the market, is now only 4% of the total market share (it was 6% in 2020), yet Toyota and Lexus together accounted for about 66% of the U.S. HEV market in 2021.

There were 43 different PHEV models sold across 13 manufacturers. The top five models include Toyota RAV4 PHEV, Toyota Prius PHEV, Chrysler Pacifica PHEV, Jeep Wrangler PHEV, and Volvo-XC90 PHEV, and together account for 63% of sales.

There were 31 different BEV models sold across 16 manufacturers. The top six models include Tesla Model Y, Tesla Model 3, Ford Mustang MACH E, Chevy Bolt, Volkswagen ID.4, and Tesla Model S and together account for 82% of sales.

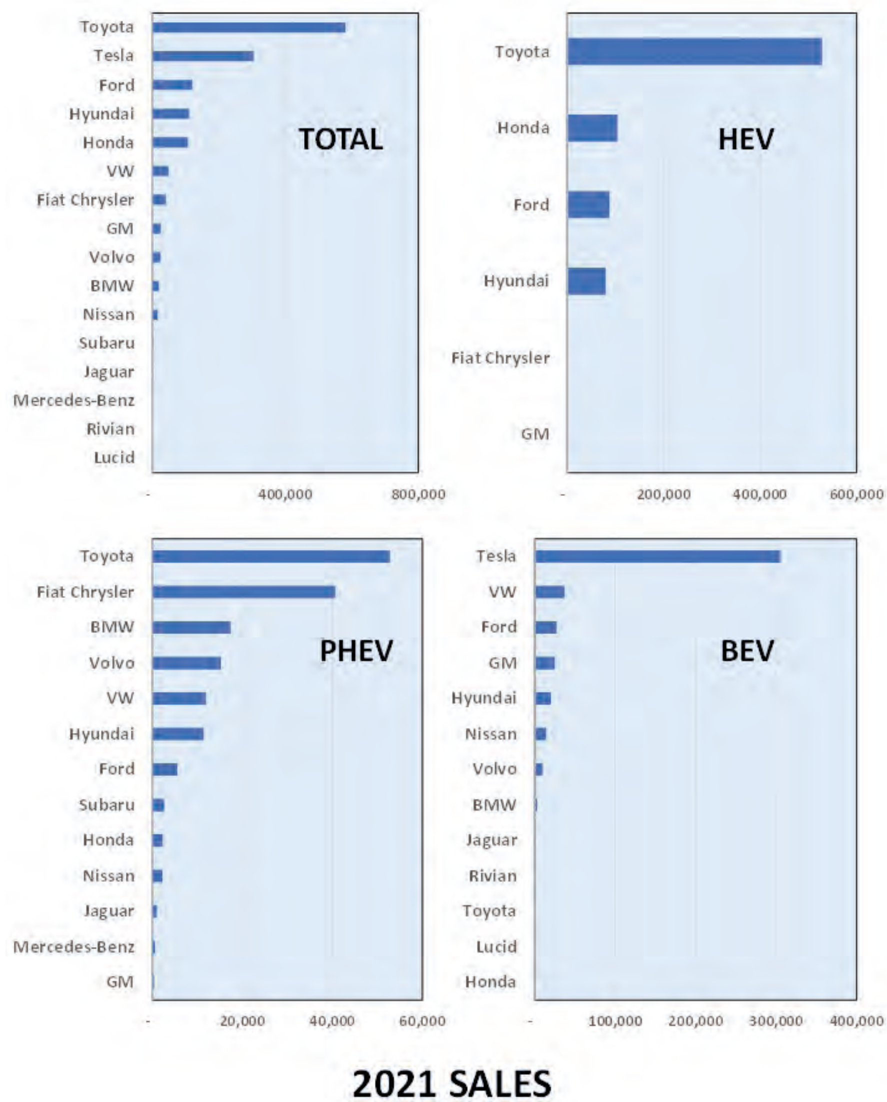


Figure 2: 2021 sales of electrified vehicles for market leaders. (Data source: Argonne National Laboratory)

Figure 3 shows the evolution of the U.S. HEV market (2006-2021) for prominent manufacturers. The corresponding information for the PHEV and BEV markets (2010-2021) appears in Figure 4 and Figure 5.

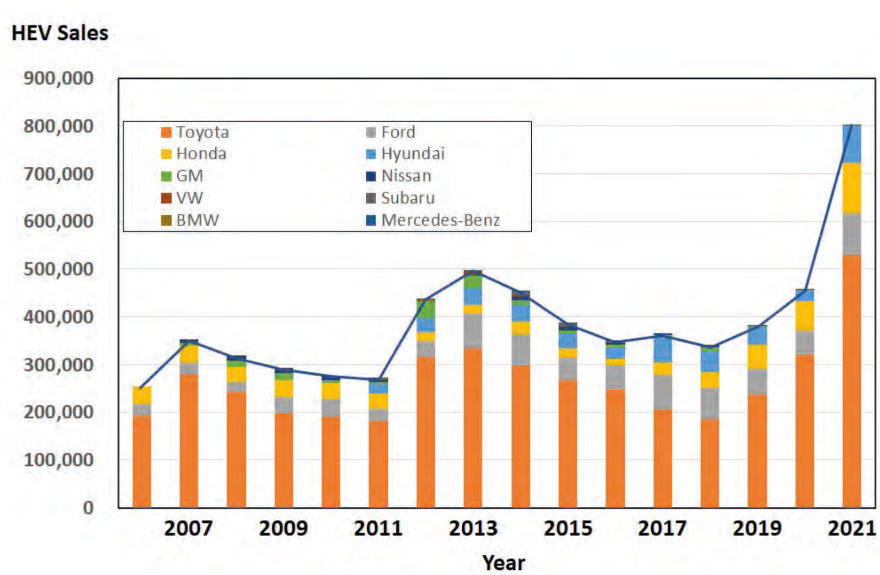


Figure 3: Evolution of the U.S. HEV market over time (2005-2021). (Data Source: Argonne National Laboratory)

Figure 4: Evolution of the U.S. PHEV market over time (2010-2021). (Data Source: Argonne National Laboratory).

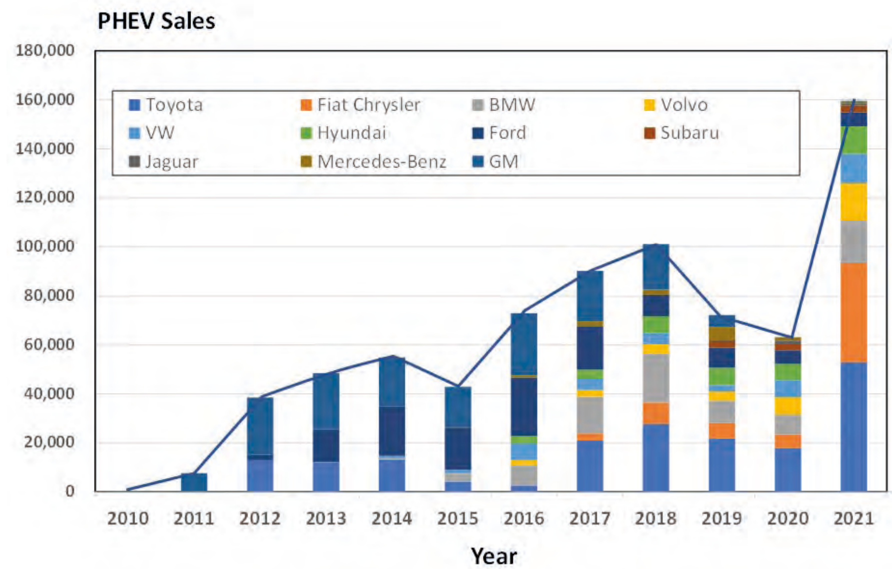
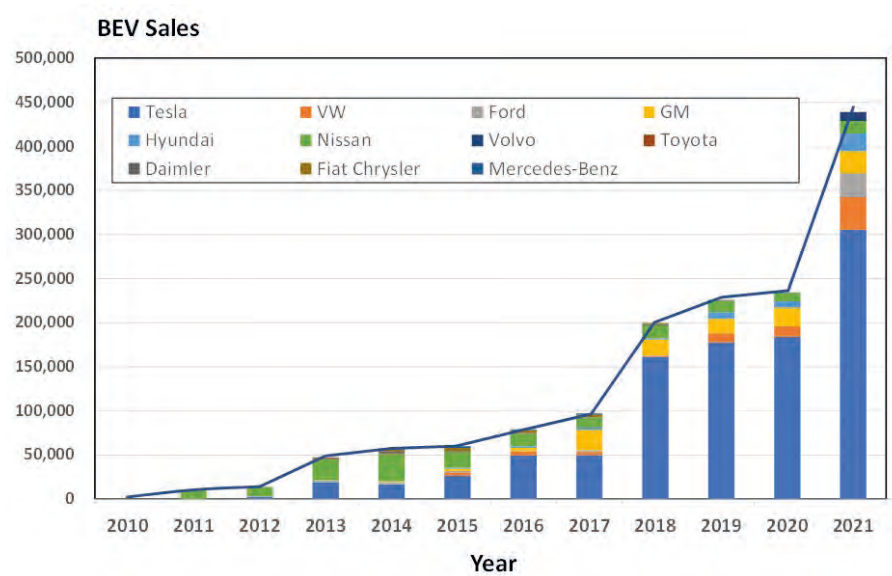


Figure 5: Evolution of the U.S. BEV market over time (2010-2021). (Data Source: Argonne National Laboratory).



The total 2021 PEV sales reached around 607,567 units, ~98% above their total sales in 2020. Eleven of the PEV models sold over 10,000 units in 2021, seven of them were BEVs. The highest-selling 2021 models included Tesla Model Y, Tesla Model 3, Ford Mustang MACH E, Toyota RAV4 PHEV, Prius PHEV, Chrysler Pacifica Plug-in, Jeep Wrangler PHEV, Chevy Bolt, Volkswagen ID.4, Tesla Model S, and Nissan LEAF (in decreasing sales order) together accounting for 78% of the combined PEV market.

The 2021 sales data also demonstrates continued dominance of Tesla's share of BEV sales; ~64% of BEV sales in 2021 (although slightly down compared to ~77% in 2020).

Table 1 provides estimated total stock and sales numbers for the electrified fleet, followed by a list of available vehicles and their respective prices in Table 2 and Table 3 for BEVs and PHEVs, respectively.

Table 1: Distribution and sales of EVs, PHEVs and HEVs in 2021.

*Total including conventional and alternative technologies

n.a. = not available
a U.S Cars
b U.S. Class 1-2 Trucks (<10,000 lbs. GVWR)
c U.S. Class 3-8 Trucks

Fleet Totals on 31 December 2021

Vehicle Type	BEVs	HEVs	PHEVs	FCVs	TOTAL*
Passenger Vehicles [a] Light trucks [b]	1,521,409[17]	6,435,669[26]	800,882[26]	12,227[26]	109,000,000[18] 144,000,000[27]
Medium and Heavy Weight Trucks [c]	n.a.	n.a.	n.a.	n.a.	13,085,000[27]

Total Sales during 2021

Vehicle Type	BEVs	HEVs	PHEVs	FCVs	TOTAL*
Electric Bicycles	278,000[19]	n.a.	n.a.	n.a.	n.a.
Passenger Vehicles [a] Light trucks [b]	443,386[26]	229,960[26] 570,421[26]	164,181[26]	3,341[26]	3,335,967[26] 11,598,274[26]
Medium and Heavy Weight Trucks [c]	n.a.	n.a.	n.a.	n.a.	758,000[27]
Totals (without bicycles)	**443,386**	**800,381**	**164,181**	**3,341**	**15,692,241**

Table 2: Market-Price Comparison of Available BEVs in the U.S.

BEV	Untaxed, Unsubsidised Sales Price (USD)	BEV	Untaxed, Unsubsidised Sales Price (USD)
Audi e-tron	$65,900	Kia Niro EV	$39,900
Audi E-Tron Gt	$102,400	Mini Cooper SE BEV	$36,650
Audi e-tron Sportback	$69,100	Nissan LEAF	$27,400
BMW i4	$55,400	Polestar 2	$38,400
Chevy Bolt	$31,500	Porsche Taycan BEV	$79,900
Chevy Bolt EUV	$33,500	Tesla Model 3 RWD	$44,900
Ford Mustang MACH E	$43,895	Tesla Model S	$94,990
Hyundai Ioniq BEV	$33,245	Tesla Model X	$104,990
Hyundai Kona Electric	$34,000	Tesla Model Y	$58,990
Jaguar I-Pace	$69,900	Volkwagen ID.4	$40,760

Table 3: Market-Price Comparison of Available PHEVs in the U.S.

PHEV	Untaxed, Unsubsidised Sales Price (USD)	BEV	Untaxed, Unsubsidised Sales Price (USD)
Audi Q5 Plug-in	$55,400	Kia SORENTO	$34,090
BMW 330e	$42,950	Lincoln Aviator Plug-in	$51,780
BMW 530e	$57,200	Mitsubishi Outlander Plug In	$36,995
BMW X5	$63,700	Porsche Cayenne S E-hybrid	$69,000
Chrysler Pacifica Plug-in	$45,400	Prius PHEV	$28,220
Ford Escape PHEV	$26,010	Subaru Crosstrek Hybrid	$35,645
Honda Clarity Plug In	$33,400	Toyota RAV4 PHEV	$39,800
Hyundai Ioniq Plug-In	$26,800	Volvo V60 Plug-in	$67,300
Hyundai Santa Fe	$33,900	Volvo XC60 Plug In	$54,250
Jeep Wrangler PHEV	$52,530	Volvo-XC90 Plug In	$64,800
Kia Niro Plug In	$24,690		

CHARGING INFRASTRUCTURE OR EVSE

Table 4 provides an overview of the number of public charging stations in the U.S. by type–including Level 1 and 2 chargers, fast chargers, and Tesla superchargers. This information is continuously collected by the U.S. DOE's Alternative Fuels Data Center (AFDC) and published on its website.[20]

It is seen that from 2019 to 2020, the overall EV charging infrastructure availability in the U.S. grew rapidly. The total number of available stations grew from 25,061 to 42,750, or by 71%. This total increase reflects the respective 78% and 40% increases in the number of Level 2 and DC fast-charging stations, which more than offsets the 3% decrease in Level 1 charging stations. The average number of plugs at each station increased by 27% for Level 2 chargers and also by 27% for DC fast chargers from 2019 to 2020.

Table 4: Information on charging infrastructure in 2021, excluding non-public charging stations. Numbers represent the total installed stations, while those in parentheses indicate the total number of available plugs. (Source: U.S. DOE AFDC, accessed February 13, 2022).

Number of Charging Stations

Chargers	2020	2021	Change
AC Level 1 Chargers	688 (1,376)	502 (1,169)	-27% (-15%)
AC Level 2 Chargers	37,113 (81,802)	42,104 (92,987)	+13% (+14%)
Fast Chargers	4,949 (17,312)	5,892 (22,278)	+19% (+29%)
Superchargers (incl. in Fast Chargers)	986 (9,726)	1,273 (12,878)	+29% (32%)
Totals	**42,750 (100,490)**	**48,498 (116,434)**	**+13% (+16%)**

Table 5: List of the top 10 U.S. States with maximum number of EVSE plugs, grouped by charging level. (Data source: U.S. DOE AFDC, accessed February 13, 2022).

Number of Charging Stations

State	AC Level 1 Chargers	AC Level 2 Chargers	Fast Chargers	Superchargers (included in Fast Chargers)
California	99 (228)	12,620 (28,981)	1,594 (6,843)	263 (3,904)
New York	11 (15)	2,616 (6,043)	200 (854)	61 (536)
Florida	21 (32)	2,204 (4,837)	304 (1,246)	82 (800)
Texas	17 (27)	2,009 (4,256)	249 (954)	67 (655)
Massachusetts	8 (9)	2,034 (4,209)	119 (444)	32 (300)
Washington	14 (80)	1,455 (3,070)	217 (727)	33 (333)
Georgia	10 (200)	1,361 (3,039)	204 (594)	29 (307)
Colorado	5 (56)	1,338 (2,935)	219 (597)	29 (259)
Maryland	9 (21)	1,005 (2,455)	195 (577)	30 (249)
Pennsylvania	3 (14)	975 (2,061)	124 (528)	44 (354)

Table 5 shows the state-level distribution of charging stations and EVSE plugs respectively for the U.S. California leads other states in the number of charging stations (nearly five times that of the next largest state of New York).
The Edison Electric Institute (EEI) and the Institute for Electric Innovation (IEI) estimated that 9.6 million charging ports will be required in the U.S. by 2030 to support EV sales. As shown in Figure 6, the vast majority of those will be needed for Level 2 home charging.[21]

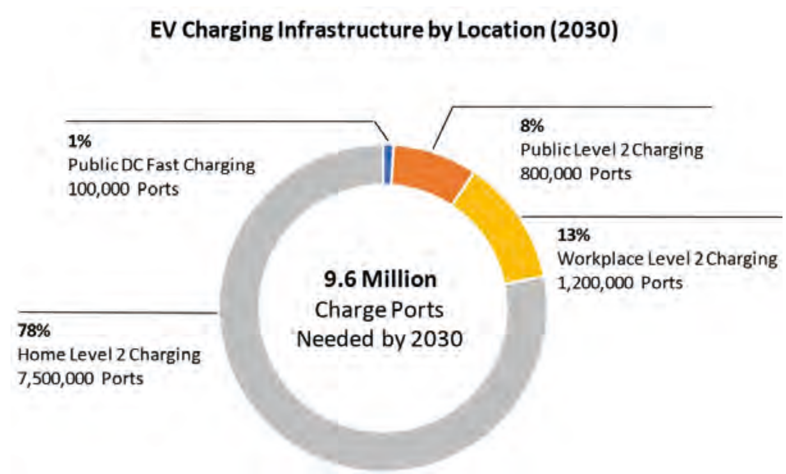


Figure 6: Projected EV charging infrastructure needs in 2030 (Source: EEI/IEI Forecast)

Volkswagen's subsidiary Electrify America has been investing in a 10-year, $2 billion ZEV infrastructure, access, and education program (of which $800 million will be spent in California and $1.2 billion in the rest of the United States). This plan was set up from Volkswagen's emissions tests software settlement with U.S. federal regulators for diesel vehicles.[22]

Over the past three years, Electrify America has set up 800 EV charging stations and about 3,500 individual ultra-fast chargers open or with construction completed in the U.S. As part of its national charging network in the U.S., Electrify America has more than 200 charging stations and over 830 individual chargers in the state of California[23]. The charging stations feature ultra-fast DC chargers that range in power from 150 kilowatt (kW) to 350kW – the fastest charging speed available today. By 2026, Electrify America plans to more than double its infrastructure, with 1,800 charging stations comprised of 10,000 individual chargers in the United States and Canada.

OUTLOOK

The only DOE-published electric vehicle market projections appear in the Energy Information Administration's (EIA) Annual Energy Outlook (AEO)[24]. The 2021 AEO Reference case represents its best assessment of U.S. and world energy markets through 2050, using key assumptions intended to provide a baseline for exploring long-term trends. EIA based the economic and demographic trends reflected in the Reference case on the current views of leading economic forecasters and demographers – assuming improvements in known energy production, delivery, and consumption technologies, but no changes in current laws and regulations for the energy sector. Projections of light-duty vehicle sales are shown in Figure 7.

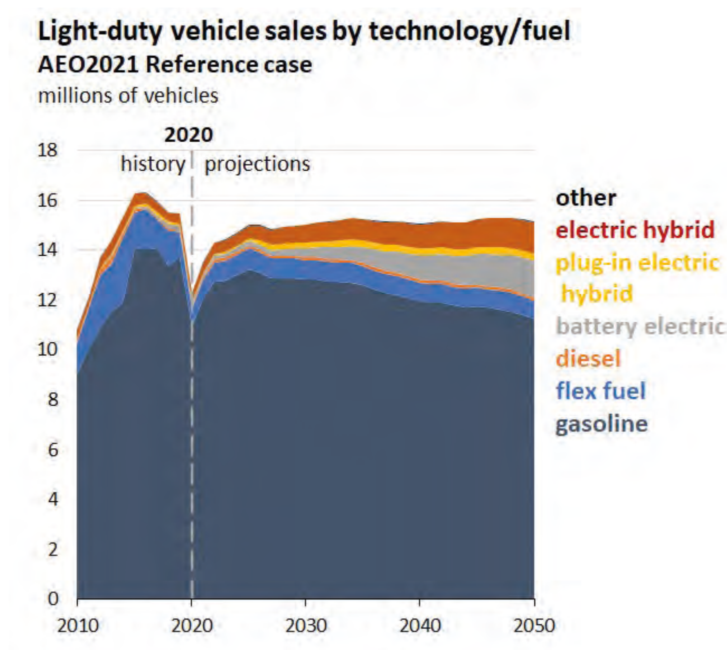


Figure 7: Light-duty vehicle sales by technology/fuel (Source: 2021 Annual Energy Outlook)

According to a study by researchers at the Institute of Transportation Studies at the University of California, Davis (ITS-Davis), California's transition to zero emission vehicles (ZEVs) will begin to save the state money by as early as 2030. The study shows that the initial higher vehicle costs over the next decade in the ZEV scenario are eventually repaid through lower fuel costs, particularly for electric vehicles.[25] Another study by the research firm IHS Markit shows that U.S. demand for electric drive vehicles, including hybrids, could rise to 1.28 million by 2026, with more than 130 models, from 43 brands, offering electric drive. About two-thirds of those sales would belong to the top 10 brands, dominated by Tesla.[26]

Global sales of light, medium, and heavy duty PEVs are estimated to continue growing, according to forecasts from Bloomberg New Energy Finance, which forecasts that EVs will become cheaper to make than gasoline vehicles and will globally sell 30 million units in 2030.[27] Electrification remains an integral feature of self-driving cars, as evidenced by ongoing test projects at Ford, GM, Uber, Waymo and other auto industry members. As it achieves key target performance and cost levels, the share of electrified vehicle miles could increase substantially.

DOE also supports two models for modeling potential electric vehicle market scenarios. The NREL Automotive Deployment Options Projection Tool (ADOPT) is a vehicle consumer choice and stock model which estimates the impact of vehicle technology improvements on future U.S. vehicle sales, energy use, and emissions[28]. The ORNL Transportation Energy Evolution Modeling (TEEM) Program facilitates understanding of efficient and effective transition from the current petroleum-based transportation energy system to one that is more sustainable and energy-diverse. It focuses on modeling market dynamics related to emerging light-duty vehicle powertrain technologies and predicting their impacts and acceptance -concentrating recent research on the potential for electrification of the highway vehicle fleet.[29]

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